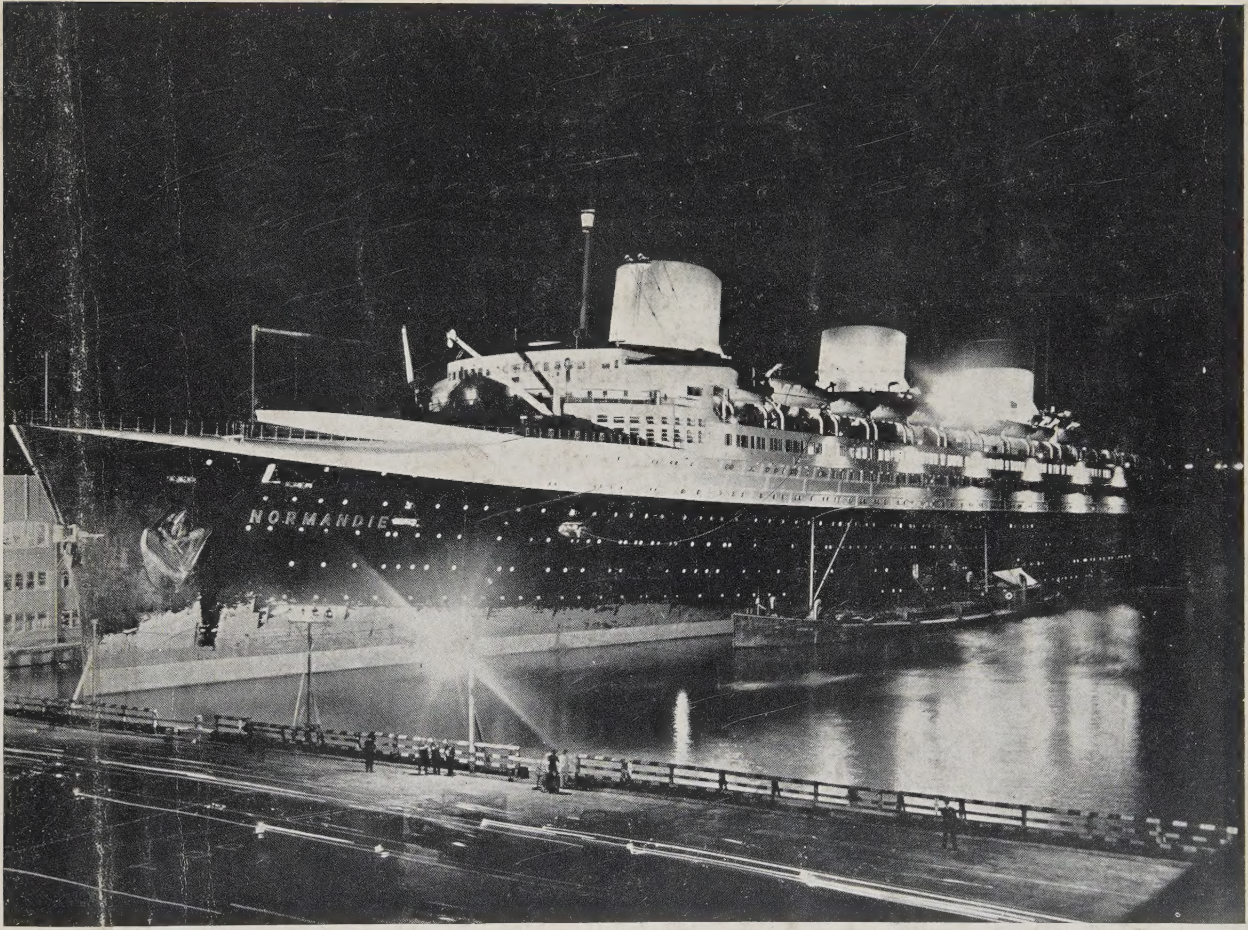
Electrical Engineering

July
1935



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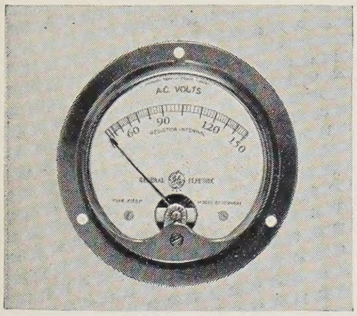

Small Panel Instruments
(Bulletin GEA-1239)

Precision Potentiometers
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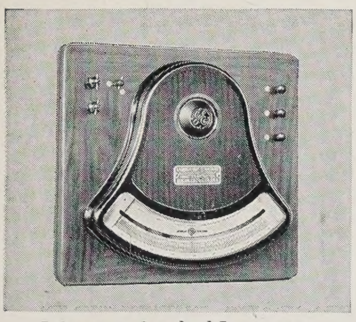

Laboratory Standard Instruments
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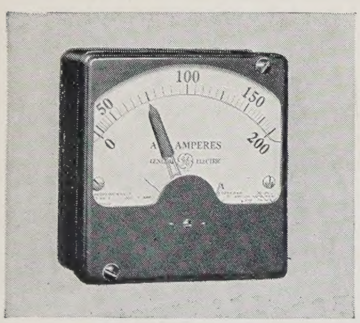

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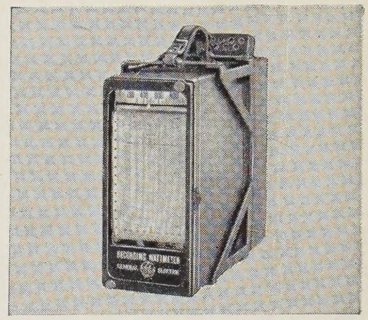
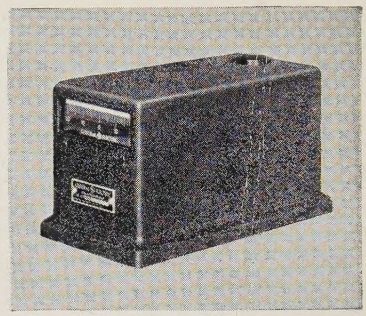
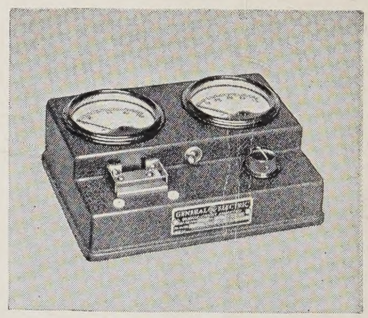


Recording Instruments
(Bulletin GEA-1061)



Galvanometers
(Bulletin GEA-2136)



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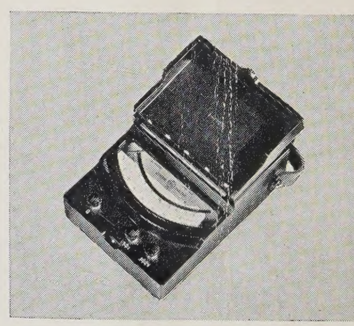
(Bulletin GEA-1943)



Medium-size Portables
(Bulletin GEA-1784)

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ATEMENTS and opinions given in articles bearing in "Electrical Engineering" are the pressions of contributors, for which the titute assumes no responsibility. Corre-ondence is invited on all controversial tters.

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This Month—

Front Cover

The turbine-electric liner "Normandie" at night after it docked in New York harbor at the completion of its record-breaking maiden trip from France on June 3. Its own lights were augmented by a half dozen 1,000 watt floodlights installed along the pier. The 4 40,000 horsepower propelling motors are reported to be the largest motors ever built for any purpose.

Photo courtesy General Electric Company

Special Articles

A.I.E.E. Papers

—Turn to next page

Discussions

Cables

Communication

Education

Electric Welding

Electrical Machinery

Electronics

Illumination

Induction Motors

Instruments and Measurements

Power Transmission and Distribution

Transformers

News 783

INCREASING application of the synchronous machine necessitates a critical investigation of the principles underlying its operation. The increasing importance of exact knowledge of machine performance when saturated requires that the designer be able to calculate accurately the leakage reactances of the machine. In one paper in this issue a method is proposed that makes possible a direct determination of the leakage reactance drop (*pages 700–05*). In many analyses of machine performance it is important also to take armature resistance into consideration. In a companion paper to the foregoing, the results of a series of tests of armature resistance under various conditions of operation are reported (*pages 705–09*).

GREATER dissemination to engineers of information regarding their professional societies and the joint organizations which carry on different phases of the work, was the purpose of a meeting of the officers and directors of these bodies held in New York, N. Y., May 20, 1935. At this meeting, each of the 8 functional organizations sponsored jointly by the 4 national engineering societies was made the subject of an address. Believing that all engineers are interested in the purposes and activities of their engineering societies, these addresses are published essentially in full text in this issue (*pages 788–94*).

DEFINITE plans whereby the engineering profession may obtain more adequate recognition as a profession have been announced by the Engineers' Council for Professional Development, joint organization of 7 national engineering societies. The E.C.P.D. has undertaken to define minimum qualification of education and experience, the fulfillment of which will enable an engineer to be "certified into the profession." The certification program developed is now under consideration before the governing boards of the societies sponsoring the E.C.P.D. (*pages 786–7*).

VACATION plans of many members will include attendance at the Institute's 1935 Pacific Coast Convention, to be held at Seattle, Wash., August 27–30. The country surrounding Seattle is well known for its scenery, including mountain ranges and national parks. The technical program, entertainment features, and inspection trips have been arranged. Two Student sessions have been scheduled and the titles of the Student papers are given in the "tentative technical program" (*pages 783–4*).

PRODUCTION of steam from electric energy has proved to be a highly satisfactory method of utilizing surplus and off-peak power where hydroelectric power is abundant. Large electric steam generators use the water itself as the resistance element. Equipment of this type now installed totals more than 1,500,000 kw in Canada and about 200,000 kw in the United States; the individual units range in size up to 42,000 kw (*pages 712–19*).

PRESIDENT J. Allen Johnson's opening address at the Institute's summer convention being held on the campus of Cornell University, Ithaca, N. Y., just as this issue goes to press, is published in the "news" section of this issue (*page 785*). A complete report of the 1935 summer convention activities is scheduled for inclusion in the August issue.

SEVERAL steep transmission line spans were found to be necessary to transmit power from the Boulder Dam plant to the switching station on the rim of the canyon above the plant. A simple and accurate method of compiling stringing charts was developed for these spans; it is applicable also to spans of any degree of inclination (*pages 719–28*).

IN AN EFFORT to classify the various species of the genus Electrical Engineer, a prominent engineering educator has made an analysis of the membership of the A.I.E.E. On the basis of his findings he makes several recommendations for improving the nomenclature of electrical engineers (*pages 695–9*).

THE Institute's board of directors presents in this issue its annual report to the membership for the year ending April 30, 1935. The report contains the usual financial statements and a brief review of the principal activities of the Institute for the year (*pages 735–47*).

TWO methods of obtaining steady state solutions for circuits containing magnetically saturated synchronous machines are given in this issue: One involves the use of equivalent reactances or impedances; the other, the superposition of current diagrams (*pages 728–34*).

AMERICAN Engineering Council, the "Washington Embassy" of engineers, continues to supply news of affairs in Washington, prepared from the engineer's point of view. Increased participation in national affairs is urged upon engineers (*pages 795–6*).

PRIZES presented by the Institute and several of its Districts for papers presented during 1934 were announced in ELECTRICAL ENGINEERING for June 1935, page 677. Awards made by 2 additional Districts have recently been announced (*pages 785*).

ADDITIONAL plans for the A.I.E.E. Great Lakes District meeting, which will be held at Purdue University, West Lafayette, Ind., October 24–25, 1935, have been made, and the subjects of several of the technical papers announced (*page 785*).

ELLIPTIC integrals often are used in calculating mutual and self-inductances of cylindrical coils. Tables of complete integrals of the first kind for large moduli are published in this issue (*pages 709–11*).

Structure of the Electrical Engineering Profession

By THEODORE J. HOOVER
Stanford University, Calif.

What is the structure of the electrical engineering profession? What are the chief branches of the profession recognized today, and relatively how many engineers are engaged primarily in each branch? What are the relationships of each branch to the other special branches? In an effort to clarify these questions, a quantitative study has been made of the membership of the A.I.E.E. and is reported herewith. On the basis of his findings, Dean Hoover makes several recommendations for improving the nomenclature of electrical engineers. Discussion is invited.

DEVELOPMENT of many new fields of engineering in recent years and the rapid growth of the tendency for engineers to specialize in certain fields have made acute the necessity for attempting to classify, for practical purposes, the main branches of the various traditional fields of engineering—civil, mechanical, electrical, mining, and chemical. This is not a matter of mere academic interest, but is of high practical concern to engineering educators, to officers of national societies whose memberships have widely varying professional fields of practice, to those dealing with state licensing and registration of engineers, and to every active engineer who desires to understand the place he occupies among the members of his profession and to define his relationships to other parts of our complicated social structure.

What are the main branches of electrical engineering? At first thought, it would seem to be an easy task to name those branches in which large numbers of electrical engineers are engaged. Anyone who has attempted to make such a list, however, soon is brought to a standstill because of the lack of any uniform nomenclature or reliable statistics on this point.

Although electrical engineering is comparatively a latecomer among the major fields, it has by far the greatest profusion of titles. No less than 3,753 different titles were discovered among those given in the 1931 Year Book of the A.I.E.E. More than 500 different kinds of engineers were found, ranging from "accounting engineer" and "acting engineer" to "X-ray engineer" and "yard engineer." Moreover, at least 8 different types of professional titles were distinguished. Of these types, the more important are those designating *general field* (electrical, civil, mechanical, mining, and chemical), *rank* (assistant, chief, etc.), *zone of interest* (acoustical, automotive, battery, etc.), and *engineering function* (design, production, research, sales, valuation, etc.). Of all the various titles found, only a few designated general field; only 9 per cent of the group described themselves merely as "electrical engineer," and it would seem that this historical scheme of classification has been broken down considerably into its elements. Although some titles given were descriptive of the special zone of interest and function of the engineer, the largest group of titles was that designating rank.

An attempt to present a cross section of the electrical engineering field at the present time through a study of professional titles is admittedly difficult. Yet, since it seems that neither census records nor the divisions and technical committees of the national society give a complete picture, anyone wishing to make a quantitative fact-analysis of these special branches can approach the question only by using as his data the titles by which the engineers themselves designate their specialties. Such a preliminary analysis is reported in this article, in the belief that it will be of no little interest to all men in the electrical engineering group.

A Study of Engineering Titles

The Year Book of the A.I.E.E. for 1931 was chosen as most representative of recent years for this particular purpose. An alphabetical frequency list of every variation of title given after the names of all the members in that year was prepared and was classified in several different ways in an effort to reveal the true structure of the electrical engineering field.

In making these classifications, it became clear that the effort to obtain an unclouded picture of the electrical engineering field was complicated by several kinds of misleading usages in title nomenclature. The most confusion was created by the fact that many of the words used have no well defined and widely accepted meanings. How should all these various labels be interpreted? Many anomalous titles would disappear at once if definitions were drawn properly and consulted at the time an engineer chooses the professional title he wishes to use in all his relations. The need for definitions is especially apparent in the use of words describing the proper functions of engineering; such words as "research," "development," "organization," "valuation," "distribution," and "management," although frequently used, seldom mean quite the same things to different persons.

Further difficulty is caused when titles are chosen that are not primarily *descriptive*. What is the value of a professional title that does not inform others of the functions the engineer performs and the place he occupies in the vast domain of engineering activities?

Written especially for Electrical Engineering, this article is one of a series of similar studies on the structures of the main fields of engineering, others of which are being published elsewhere. Those interested in the general program of the studies, and the results of a study of the engineering profession as a whole, are referred to "The Structure of the Engineering Profession," by Theodore J. Hoover, *Journal of Engineering Education*, January 1935, pages 356–72. Manuscript submitted April 8, 1935; released for publication April 19, 1935.

The need for this criterion becomes at once apparent to anyone who has examined the exotic and chaotic collection of titles given by electrical engineers at the present time. Unless a title is informative to those who hear it, the engineer is open to suspicion that vanity or even less agreeable motives have impelled his selection.

Confusion also arises from the widespread lack of discrimination between a man's *professional title* and the designation of his current *position;* in the directory, these 2 are used indiscriminately. A man, for example, may have devoted his career to "illumination engineering," and for the purpose of this study the fact that he is at present "assistant superintendent, street lighting department" is of no great concern. A great many titles in the list evidently are titles of rank in a large corporation, which, although they might signify much to the corporation's executives, convey no meaning at all to the general public or even to other engineers. The designation of his rank and place in some organization is usually a transitory thing, and a matter over which the engineer has no control; but he certainly should take great care, when choosing his professional title, to select those words that most appropriately describe his special interest throughout a considerable period of practice.

Again, the unmodified term "engineer," frequently found, is exact if the possessor is competent to practice in almost any segment of the broad realm of engineering; but if the man's career has been associated closely with any special branch, it is more informative and more accurate to have him designate this special interest by calling himself an "electrical engineer," a "telephone engineer," an "acoustical engineer," a "research engineer," or the like. In contrast to giving the unmodified title is the practice of putting down a too-specialized title. More than 17 per cent of the members of the Institute bear titles unique to them alone among all the thousands of their fellows; and a division of engineering that has only one representative in the whole American group cannot be a very important subdivision of that field. These 2 extremes of nomenclature are seldom justifiable and have added to the difficulty of properly interpreting the frequency lists presented next.

The basic list of all variations in titles of the 17,327 A.I.E.E. members in 1931 revealed a total of 3,753 different titles (without any attempt at grouping and considering, for example, the title "electrical and mechanical engineer" to be distinct from "mechanical and electrical engineer"). Out of these 17,327 men, 1,212, or 7 per cent, gave no title. Of the remaining 16,115 who gave titles, 907, or 6 per cent, gave simply "engineer," and 1,414, or 9 per cent, gave simply "electrical engineer." The length of the titles given varied from 1 to 15 words. There were 2,794 *unique* titles in the group, or *74 per cent* of the various different titles found. This high degree of originality is cause for wonder concerning the motives for selecting and using engineering titles.

Some titles might be considered synonymous (*e. g.*, "teacher" and "instructor") or are found in slightly differing or inverted forms (*e. g.*, "consulting electrical engineer" and "electrical engineer, consulting engineer"); but any attempt to condense the list by arbitrarily throwing together even these fairly simple variations leads to impossible confusion.

Numerical Frequency List

A first attempt was made to reduce the list on the basis of numerical frequency. The 101 most frequent titles in the list, all of which appeared 20 times or more, are as follows:

electrical engineer	1414
engineer	907
sales engineer	415
president	406
assistant engineer	392
manager	312
chief engineer	306
consulting engineer	241
vice president	234
professor	209
telephone engineer	176
assistant electrical engineer	174
superintendent	170
research engineer	161
instructor	150
district manager	132
assistant professor	129
draftsman	116
design engineer	113
chief electrician	106
engineering assistant	104
general manager	95
electrician	93
salesman	93
member of technical staff	86
vice president and general manager	86
chief electrical engineer	85
engineering department	80
electrical designer	76
junior engineer	75
associate professor	74
field engineer	71
radio engineer	71
electrical draftsman	69
development engineer	62
distribution engineer	61
electrical superintendent	61
proprietor	60
general engineer	59
general superintendent	59
transmission engineer	58
managing director	55
designing engineer	53
director	53
sales manager	52
assistant superintendent	50
consulting electrical engineer	49
foreman	46
assistant chief engineer	44
division engineer	43
industrial engineer	43
equipment engineer	42
partner	42
assistant manager	41
commerical engineer	41
district engineer	40
member of firm	39
president and general manager	39
junior electrical engineer	38
designer	37
switchboard engineer	37
district sales manager	36
testing engineer	36
construction engineer	34
mechanical engineer	34
supervisor	34
operating engineer	33
secretary	33
assistant vice president	32
plant engineer	31
inspector	30
patent attorney	30
secretary and treasurer	30
power engineer	28
meter engineer	27
student engineer	27
electrical foreman	26
electrical inspector	25
electrical tester	25
retired	25
superintendent of power	25
works manager	25
service engineer	24
substation operator	24
treasurer	24
electrical engineering department	23
local manager	23
superintendent of distribution	23
technical assistant	23
test engineer	23
assistant to president	22
general foreman	22
laboratory assistant	22
special representative	22
supervising engineer	22
tester	22
transformer engineer	22
technical employee	21
chief draftsman	20
president and treasurer	20
vice president and chief engineer	20

Although this list, based upon a count of the commonest titles used by the men in the group, takes care of 9,773 names, or 61 per cent of all who gave titles, it is still far from revealing very much in regard to many of the important branches of electrical engineering. By far the greater number of titles listed indicate *rank*, such as "president," "chief engineer," and "superintendent," rather than special technical interest. Moreover, even if only those who specifically designate themselves as engineers are considered, they may classify themselves from several different points of view. For example, it is clear that modifying words like "sales" and "research" are of a sort different from words like "telephone" and "radio," and that words like "chief" or "consulting" are of sorts different from any others.

Adjectives Modifying "Engineer"

A second attempt was made to achieve some sort of order by selecting from the alphabetical list all

adjectival terms anywhere to be found modifying the word "engineer," thus boldly ruling out all who did not classify themselves primarily as engineers. These modifying adjectives, which indicated a total of 520 branches of engineering represented by A.I.E.E. members, then were sorted into 9 groups of different categories as follows:

1. Words *"engineer"* or *"general engineer."*
2. Words designating *general field.* These comprise the major traditional engineering fields, as follows:

chemical (engineer)	electrical
civil	mechanical
electric	mining

3. Words designating *zone of interest.* Such words indicate the specific structures, materials, or products to which the specialist devotes himself, or the special technology he uses in his particular work. The list as a whole furnishes a good general description of the varied kinds of problems that may be encountered in the domain of electrical engineering:

accountant
accounting (engineer)
acoustical
acoustics
aeronautic-radio
alternating-current
apparatus
appliance
automatic substation
automatics
automotive
battery
bearings
brush
building
buildings
cable
capacitor
car-equipment
catenary
central-station
charge
circuit
circuit-breaker
circuit-breaker insulation
city
coil
combustion
commercial
commercial cable
commercial power
commercial survey
communication
communications
compass
condenser
conduit
cost
cost control
data
dial
dial equipment
direct-current
distribution-station
drafting
draftsman
electric-railway
electrical drafting
electrical hammer
electrical heating
electrical instrument
electrical railway
electrical recording
electrochemical
electrolysis
electromechanical
electron-tube
electrostatic condenser
elevator
elevator-control
equipment
exchange
exchange fundamental plan
exchange plant
exchange rate
exchange transmission facilities
facility
factory
fire-alarm
fire control
fire prevention
fire protection
fixed-capital
foreign wire relations
fundamental plan
gas
gas-works
gear
gem
generating
gyro-compass
high-frequency
high-tension
high-tension switchgear
high-voltage
hydraulic
hydroelectric
illuminating
illumination
induction co-ordination
induction motor
inductive co-ordination
inductive heating
inductive relations
industrial
industrial control
industrial gas
industrial heating
industrial power
inside plant
inspection methods
installation
installing
instrument transformer
insulating
insulator
insurance
interconnection
interference
inventory
laboratory
lamp
liaison
lighting
lightning-arrester
line
line-extension
load
long-lines
mains
manual equipment
manual switchboard
manual system equipment
marine
material
materials
mercury-arc rectifier
meter
methods
municipal
network
noise prevention
ocean cable equipment
office layout
oil circuit-breaker
outside plant
outside plant telephone
overhead
overhead system
paper mill
patent
photometric measurement
photophone
plant
plant equipment
plant extension
plant inventory
police signal
power
power apparatus
power cable
power plant
power station
power supply
power transformer
preliminary plans
process
product
projector
propeller
property
proposal
protection
protective gear
public utilities
public service
pyrometer
radio
radio interference
radio protection
radio transmitter
radio tube
railway
railway control
railway equipment
railway motor
rate
receiving
record
recording
rectifier
refrigerating
regulation
relay
relay protection
results
road
rubber mill
rural electrification
shop
signal
signal control
small motor
sound
sound projection
sound transmission
starting
station
stationary
statistical
steam
steam plant
steel mill
street
street lighting
structural
studio
substation
subway
super-tension cable
supply
survey
switchboard
switchgear
switching
switching-equipment
synchronous
system
system relay
systems studies
telegraph
telegraph equipment
telephone
telephone apparatus
telephone equipment
telephone plant
telephone practice
test methods
test plant
textile
timber products
toll
toll cable
toll equipment
toll facilities
toll fundamental plan
toll lines
toll plant
toll plant extension
toll system
toll transmission
town
traction
traffic
traffic results
traffic routing
traffic signal
traffic toll line
tramway
transformer
transformer accessories
transmission
transmission instruments
transmission line
transmission system
transportation
trunk
trunk traffic
turbine
underground
underground cable
underground system
utility
vacuum tube
voltage regulation
welding
winding
wire
wiring
works
X-ray
yard

4. Words designating *engineering functions.* The word "function" is used herein in its common meaning as "any special kind of action, activity, office, or service properly belonging to a person or thing." The engineering process, carried on from the time a particular human need is recognized until the time when that need is satisfied through organized engineering effort, may be divided into several steps, each one of which calls for the exercise of a certain function. The functional adjectives used to modify "engineer" are much fewer than those describing zones of interest, but are used in the titles of a great many more men. Since functional words are not so self-explanatory as those describing zones of interest, they should be used only when their meanings are defined clearly. The adjectives which seem to the writer to be clearly functional are as follows:

application (engineer)
appraisal
constructing
construction
contract
contracting
design
designing
development
developmental
distribution
efficiency
erecting
erection
estimate
estimating
examining
executive
experimental
inspecting
inspection
inspector
investigating
investigation
investigations
investment
maintenance
managing
manufacturing
operating
operation
plan
planning
production
purchasing
quality
research
safety
sales
service
specification
standardization
standards
superintending
supervising
supervisory
test
testing
valuation

5. Words in combinations designating (a) *field and function* or (b) *zone of interest and function.* From the point of view of descriptiveness, these combinations are excellent. They give a clear picture not only of the field or zone of interest of the specialist, but also of the particular function he performs. It should be pointed out that, in addition to those found and listed here, a great many other appropriate titles like these may be made easily by combining almost any adjective under list 2 or list 3 with almost any adjective under list 4.

alternating-current design (engineer)
apparatus development
battery service
bridge designing
broadcast receiver development
brush sales
cable development
circuit design
circuit standardization
cost control
direct-current motor design
electrical conductor sales
electrical construction
electrical design
electrical designing
electrical development
electrical distribution
electrical erecting
electrical estimating
electrical operating
electrical planning
electrical research
electrical sales
electrical service
electrical testing
electrical valuation
electrochemical research
electron-tube application
equipment development
equipment maintenance
equipment sales
exchange sales
factory planning
industrial sales
industrial service
installation service
installation supervising
lighting sales
load supervising
load supervision
motor design
outside plant development
outside plant distribution
overhead distribution
plant design
power-apparatus development
power-cable testing
power development
power sales
power station design
protection development
public utility investment
radio design
radio development
radio installation
radio research
railway sales
refinery construction
relay maintenance
service sales
station design
station equipment development
structural design
substation design

substation maintenance	transformer design
switchboard specification	transformer designing
system control	transformer sales
sytem planning	transmission construction
system test	transmission design
telephone-circuit design	transmission development
telephone-circuit development	transmission instruments development
telephone design	transmission system research
telephone installation	transmitter development
telephone systems design	turbine test
telephone systems development	underground distribution
tramway distribution	vacuum tube development

6. Words denoting *capacity* in which the engineer utilizes his knowledge and skill:

advisory (engineer)
consulting
staff

7. Words denoting *rank*. These words indicate present position held by the engineer, but are of little value in classifying the branches of electrical engineering:

acting (engineer)	director
assistant	first
auxiliary	principal
chief	second
deputy	

8. Words describing *geographical location* of the engineer. These also are of little value for classification purposes. It is likely that in reality most of them are indications of position held by the engineer rather than his special professional field:

borough (engineer)	foreign
branch	local
county district	northwestern
district	Pacific coast
division	resident
eastern	state
European	traveling

9. Words describing *professional status*. Such words are least useful of any for the purpose in view:

cadet (engineer)	professional
chartered	senior
junior	student

A few titles were found that did not fit clearly into any one of the 9 foregoing categories. Several of these, most of which appear only once in the list, impress one as being merely weird inventions which are meaningless and unnecessary.

Significant Words in Engineering Titles

For many reasons, the foregoing study of adjectives used to modify "engineer" could not yield to numerical treatment. A plan was devised which, it was hoped, would combine a numerical frequency listing with a word study such as that just described. Accordingly, the laborious task was performed of making an alphabetical frequency list of all significant words (omitting "and," "of," "in," etc.) found in the titles given. Certain variant words from a single root were listed together, *e. g.*, "generat(ing)(ion)(or)," or "manag(er)(ement)(ing)," since all these variants were taken to represent virtually the same idea.

A total vocabulary of 718 significant words (plus their variants) was found in the titles given. These words appeared 34,256 times, making 2 significant words the average number for each title. These significant words then were classified according to groups of categories similar to those used in the study of adjectives modifying "engineer," as already defined, and a frequency count was made of the total times each was used in the titles. Only a summary of this revealing word list can be given here (table I).

This summary seems to show that words indicating general field (2), zone of interest (3), engineering functions (4), and rank (6) are preponderant among all the types used in the engineering titles found. The fairly low frequency of words designating general field (chemical, civil, electrical, mechanical, and mining) reveals that the traditional classification has been broken down largely among electrical engineers; this is further evidenced by the fact that of all those giving titles, only 9 per cent gave simply "electrical engineer."

Table I—Summary of Results of Numerical Frequency Study of Significant Words in Engineering Titles

	Category	Number of Significant Words + Variants	Number of Times Such Words Appeared	Per Cent of Total Times
1	Words *"engineer"* or *"engineering"*	2	8,751	26
2	Words designating *general field* (chemical, civil, electrical, mechanical, mining)	5	3,023	9
3	Words designating *zone of interest* (acoustical, battery, cable, etc.)	322	5,162	15
4	Words designating *engineering functions* (appraisal, construction, design, etc.)	52	6,590	19
5	Words designating *capacity* (advisory, consulting, expert, etc.)	29	1,693	5
6	Words designating *rank* (acting, assistant, chief, etc.)	50	5,235	15
7	Words designating *geographical location* (American, borough, branch, etc.)	70	1,124	3
8	Words designating *professional status* (apprentice, cadet, junior, professional, etc.)	25	370	1
9	Words designating occupations *not primarily engineering* (accountant, attorney, banker, etc.)	50	419	1
10	*Miscellaneous* words (mainly auxiliary, or not clearly belonging to a previous group)	113	1,889	6
	Totals	718	34,256	100

Rank is independent of function or zone of interest; it is something that comes by promotion whereas function or zone represents the man's particular type of education and his chosen sphere of activity. The high frequency of use of words designating rank would support the belief that this type of title should be given separately from professional title. If this be done, it then appears that 3 types of descriptive words—those here termed as designating *general field*, *zone of interest*, and *function*—are used predominatly, and it seems clear that all these types should be included in any scheme proposed for classification of engineers. The remaining types of words —those here termed as designating *capacity*, *geographical location*, *professional status*, and *not primarily engineering*—are not used greatly at present, although they may be needed, in combination with titles of rank, to indicate a man's present position in an organization; such words might well be left out of consideration in planning a standard system of classification of engineers by professional title.

Recommendations

Rapid increase in specialization among electrical engineers has brought with it an urgent necessity to attempt to establish some standard scheme by which

the recognized branches of the profession and the titles of engineers devoting themselves to special branches might be designated. The adoption of a good standard scheme would be of great practical value to engineering educators, to officers of national engineering societies, to those concerned with the licensing of engineers, and to all active engineers who

1. Profession or occupation: ______________________

NOTE: If you are an *engineer*, please give above your professional title, by prefixing to the word "engineer" one of the adjectives in either list *A* or list *B* below, or a combination of an adjective in list *A* and one in list *B*. For example:

Electrical engineer (from list *A*)
Acoustical engineer (from list *A*)
Research engineer (from list *B*)

Acoustical research engineer (combined from list *A* and list *B*)
The word "consulting" may be added before any title if required. A double title may be given (*e. g.*, "electrical and mechanical engineer," "design and construction engineer," "professor and electrical engineer"). Adjectives in titles need not be restricted to those in the lists below

List A
(Fields and Zones of Interest)

Acoustical	Power
Apparatus	Power-plant
Cable	Protection
Central-station	Public-utility
Chemical	Radio
Circuit	Railway
Circuit-breaker	Railway-equipment
Civil	Rate
Combustion	Recording
Commercial	Relay
Communications	Signal
Condenser	Sound
Control	Specifications
Cost	Station
Electrical	Steel-mill
Electrical heating	Street-lighting
Electrochemical	Structural
Electrolysis	Substation
Equipment	Switchboard
Exchange	Switchgear
Hydraulic	Telegraph
Hydroelectric	Telephone
Illuminating	Telephone-equipment
Industrial	Traffic
Installation	Transformer
Laboratory	Transmission
Mechanical	Underground
Meter	Vacuum-tube
Patent	Works
Plant	Other zone of interest:

List B
(Engineering Functions)

Application	Managing
Appraisal	Manufacturing
Construction	Operating
Contracting	Planning
Design	Production
Development	Research
Distribution	Safety
Efficiency	Sales
Erection	Service
Estimating	Standardization
Executive	Supervising
Experimental	Test
Inspection	Valuation
Investigation	Other function:
Maintenance	

2. Present position and rank (*e. g.*, "superintendent, power division, ———— Electric Company," "assistant professor of radio engineering, ———— University"):

____

Fig. 1. Model form for classifying electrical engineers suggested by author as part of a blank to be submitted to A.I.E.E. members when soliciting information for A.I.E.E. Year Book

themselves desire to understand the place they occupy in the structure of their profession and to inform the general public of their position in modern industry.

For this reason, the following proposals are offered for discussion as possible steps toward the establishment of an improved nomenclature for electrical engineers:

1. That all men primarily engaged in work of an engineering nature—applied scientists as distinguished from pure scientists on the one hand and from nonprofessional technicians on the other—use the word "engineer" as a part of their professional titles. Titles such as "draftsman," "mechanic," "electrician," "machinist," and "designer" should be reserved for the nonprofessional artisan. If the man is actually an engineer, it seems clear that he should use that word in his title.

2. That all engineers be asked to make a distinction between *professional title* (indicating the branch of engineering to which their careers have been devoted) and *present position* (indicating the place and rank they occupy in an organization). At present these 2 kinds of titles are used indiscriminately.

3. That all professional titles be composed of 2 types of adjectives: first, adjectives indicating special *field* or *zone of interest*, and second, adjectives indicating special *function* performed. These combination titles would be of such a sort as "electrical research engineer" or "transformer sales engineer." In certain instances, words indicating special *capacity* might need to be prefixed (*e. g.*, "consulting electrical research engineer").

4. That in choosing an appropriate professional title, the engineer might best describe his activities by using one of the 4 following combinations:

(*a*) If the engineer is competent to practice in all branches of engineering, he should designate himself as "general engineer."

(*b*) If the engineer considers himself to be a specialist in all functions in a particular *field* or *zone of interest*, he should designate himself as "general electrical engineer," etc., or as "general telephone engineer," "general power engineer," etc.

(*c*) If the engineer considers himself to be a specialist in all fields or zones of interest in a particular *function*, he should designate himself as "general research engineer," "general design engineer," "general sales engineer," etc.

(*d*) If the engineer considers himself to be a specialist in a certain *field* or *zone of interest*, and likewise in a certain *function* in that field, he should designate himself by a combination of these 2 types of titles, such as "electrical research engineer," "telephone design engineer," "power sales engineer," etc.

Using only the words to be found in the lists of adjectives previously given, each of which may be defined rigidly in small space, it is possible according to this recommended scheme to make up several thousand different combination titles of this sort that are highly descriptive and the meanings of which may be at once clear. This plan of building titles from interchangeable words would be flexible enough, it is believed, to permit a good classification of engineers indefinitely, since new words may be admitted to the lists when demanded to describe new functions and new zones of interest taken over by the profession. The practical working of the foregoing proposals is exemplified in a classification form here suggested for consideration as part of the blank sent to A.I.E.E. members to obtain directory information (see figure 1).

5. That, since most of the words descriptive of electrical engineering functions are not self-explanatory, a list of definitions be composed and agreed upon to delimit the indiscriminate use of these terms.

It is considered important for scientists and engineers to classify with great care the natural objects, products, and materials they study and handle. How much more important, then, should it be to give attention to the classification of the various species of the genus Electrical Engineer, the members of which have had such a hand in the making of the modern world! The writer feels strongly that any attempts at this time to promote among the engineering fraternity a more logical scheme of classification of the branches of engineering cannot but lead to valuable results in greater understanding of the logical divisions of the profession, to clarification of the differences that distinguish one branch from another, and to better comprehension of the qualities requisite for success in each branch.

Test Values of Armature Leakage Reactance

Armature leakage reactance of synchronous machines has recently received considerable attention because of the important part which it plays in the accurate calculation of the performance of the saturated machine. (See, for example, reference 15 at end of this paper.) Test methods for determining the proper values of armature leakage reactance, and the results of these tests, are presented in this paper and should be of interest as an indication of the reliability of the formulas for the unsaturated value of this reactance and also as an indication of the variations in the reactance due to machine saturation. This paper is a companion paper to "Tests on Armature Resistance of Synchronous Machines" appearing on pages 705–9 of this issue.

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THE ever increasing application of the synchronous machine, and its growing importance in the problem of power system stability, have quite recently necessitated a more critical investigation into the physical principles underlying the machine operation. Rapid advances made in the last 8 years have subjected to review the implications of the 2-reaction theory, and have brought forward many additional problems, one of these being the performance of the machine under conditions of saturation.

The increasing importance of exact knowledge on machine performance under conditions of saturation requires that the designer be able to calculate accurately the leakage reactances of the machine so that values of excitation may be determined for the various important load conditions. Present methods of calculation take saturation into account somewhat empirically, giving results sufficiently close for many problems. However, in other cases the results are not satisfactory, and greater accuracy is desired. It is, therefore, important that the physical concepts of armature leakage reactance and its relation to machine performance be critically reviewed and design formulas be compared with test data.

A paper recommended for publication by the A.I.E.E. committee on electrical machinery, and scheduled for discussion at the A.I.E.E. Pacific Coast convention, Seattle, Wash., August 27–30, 1935. Manuscript submitted May 6, 1935; released for publication May 27, 1935.

Developments of Concepts and Methods of Calculation

Calculations on leakage reactance were unorganized until C. A. Adams[1] correlated in one paper the ideas of previous authors and redeveloped the expressions in a more logical manner. Adams' work was confined entirely to the induction motor, stress being placed on its design and operating characteristics. Practically no work was done in the synchronous machine until Fechheimer[2] investigated the relationship of leakage reactance upon motor starting characteristics. His was the first extensive study of this quantity and its effect upon the characteristics of the synchronous machine and it led to a better understanding of the phenomena taking place within the motor.

The term transient reactance was introduced by Durgin and Whitehead[3] in the same year as Fechheimer's study, 1912, to explain the action of the armature current under short circuit. This reactance included the effect of both field leakage and armature leakage fluxes. A further and more complete study was made by Doherty and Shirley[4] in 1918 on the armature leakage reactance and its bearing upon the subject of alternator short circuits. The paper by Doherty and Shirley was the first attempt to develop a single expression that could be used in the calculation of armature leakage reactance for all lines of synchronous machines.

Little more was done on the development of theoretical expressions for leakage reactance until the entire theory of synchronous machine operation was reviewed to consider the variation of armature reaction with pole position. The papers by Doherty and Nickle[5] have thrown an entirely new light upon the subject of synchronous machine operation, and, as a consequence, the ideas underlying the definitions of armature leakage reactance had to be modified in correspondence with the new theories. The task of developing new expressions for this reactance, in conformance with the newer concepts, was accomplished by Alger[6] in 1928. The derivation of Alger's expressions is based upon a better physical knowledge of the factors involved and upon a more rigorous mathematical treatment than that of any previous writer. The more recent study by Kilgore[7] presents the subject from a somewhat different viewpoint, in that flux plotting methods are employed to determine expressions for several of the reactance components. Numerical calculations for a given machine indicate that there is little difference in the results obtained by the methods of either Alger or Kilgore.

The concept of what is meant by armature leakage reactance has not changed too greatly from the first ideas on it until the present definitions. It is interesting to note that the expression for slot leakage flux used in the present day calculations is not much different from that developed by Dick[8] and Fischer-Hinner[9] in 1898 for the d-c machine. The

1. For all numbered references see list at end of paper.

expressions for the end connection, zig-zag, tooth-tip, and belt leakage fluxes have varied greatly, and until the work of Alger and Kilgore little correlation of ideas existed. In view of the recent development of the 2-reaction theory of synchronous machines, there arose the necessity of redefining certain components of the armature leakage reactance so as to maintain conformance with the general theories. These later definitions will be adhered to throughout this discussion.

Definition of Armature Leakage Reactance

In the very early studies on synchronous machines, there was only one reactance, armature leakage reactance, this value being used to determine the inherent regulation of a loaded alternator. Later it was found necessary to combine with this term a second quantity which included the effects of armature reaction, the sum of these 2 effects to be called synchronous reactance. However, just where the exact line of demarcation between armature reaction flux and armature leakage flux can be drawn never has been answered fully. Armature reaction flux can be thought to exist only under conditions of no saturation.

Initially, it was considered that armature reaction was merely equivalent to the action of a coil moving along the armature surface, combining vectorially its ampere-turns with those of the main field winding. Because armature reaction exists only at the armature surface, hence not having quite the same effect as though due to the field winding, and because the principle component of magnetomotive force which is stationary with respect to the poles is sinusoidally distributed, the original concept of armature reaction has been modified slightly. Armature reaction, therefore, is understood to refer to the fundamental or stationary component of armature magnetomotive force. There has been the question, however, whether it should include the synchronous magnetomotive force in the end windings or should relate only to the stacked length of the armature.

Theoretically, it seems desirable to treat armature reaction as due to the fundamental components of magnetomotive force in both the end windings and the stacking length. For practical computations however, it appears better to limit the term only to the magnetomotive force in the stacked length of the machine. In normal salient pole machines, the errors introduced by this manner of definition are negligible. From this viewpoint, armature leakage reactance is an arbitrary component of the synchronous reactance and is due to the difference between the space fundamental of flux in the air gap and the flux produced by the armature current acting alone for the case of no field magnetomotive force.

Doherty and Nickle[5] define armature leakage reactance as the difference between the total synchronous reactance and the reactance of armature reaction. Specifically, they state: "The voltages induced by the space fundamental magnetomotive forces existing within the limits of the armature core are taken as the reactance voltages of armature reaction, and the voltages produced by space harmonic magnetomotive forces within these boundaries are classed as leakage reactance voltages, ordinarily referred to as due to tooth-tip and belt leakage. . . . . . In addition, there are also leakage reactance voltages due to slot and end turn fluxes which are independent of rotor position."

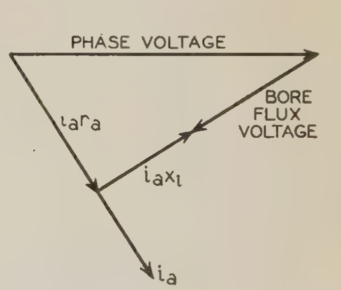
Application of Armature Leakage Reactance

Consideration of armature leakage reactance as above defined leads to a greater practical application in synchronous machine studies. The total armature leakage reactance, while purely fictitious with no existence as a separate quantity, is open to practical application in the design of machines, being one of the components determining the air gap voltage. Recent studies on the saturated machine[10] employ both the effective armature resistance and the armature leakage reactance in calculating the air gap voltage under load in order to determine the actual flux existing within the machine and the additional field ampere turns necessary to overcome the saturation in the iron paths.

Within the last 2 years, the development of circuit breakers and relay circuits has brought the transient stability limit of the transmission system closer and closer to the steady-state stability limit. It became necessary therefore, to calculate as accurately as possible both stability limits to insure continuous operation where firm power has been guaranteed. To this end, the theory of synchronous machines has been reviewed to include the effects of saturation upon the operating characteristics of the machine in connection with the entire system, and, as a consequence, armature leakage reactance must be known definitely.

The more exact theory suggested by Crary, March, and Shildneck,[10] on the influence of saturation in

Fig. 1. Vector diagram for the air-core test



machines, is based upon a knowledge of the air gap flux and the air gap voltage generated by this flux, as this is a measure of the saturation. It was the aim of that paper to develop a series of expressions that could be used in representing the actual saturated machine by an equivalent unsaturated machine having similar angle, excitation, and stability characteristics to those which the actual machine would have under the assumed conditions. From these expressions the synchronizing power could be predicted with much greater accuracy than that obtained from the unsaturated theory.

In the discussion of Crary, March, and Shildneck, the assumption is made that the leakage reactance

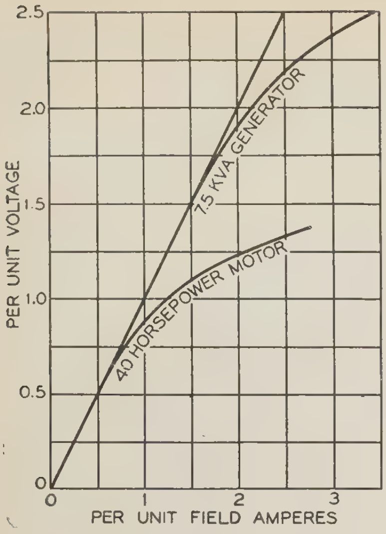


Fig. 2. Comparative saturation curves of the 2 machines

Rated values taken as unity

does not vary from the calculated unsaturated value when the machine is operating well up on the saturation curve. Under these conditions the stator teeth and the stator iron may be highly saturated and hence reduce the leakage flux per ampere for the slot, tooth-tip, and belt components. The calculated value of air gap voltage, obtained from the terminal voltage, resistance drop, and the calculated value of armature leakage reactance drop, will be higher than the actual value existing within the machine for the over-excited condition of operation. As a consequence, the additional field ampere turns or the equivalent values of the synchronous reactances determined from this air gap voltage will give, when used in the performance calculations, results which indicate that the machine may have greater stability than it actually has. The stability limit calculated for the machine in this manner may be too high, and would lead to optimistic conditions of system operation.

Because of the complications introduced by the non-linearity of the saturation curve, it is difficult if not impossible to determine, from theoretical considerations only, the saturated values of armature leakage reactance. It is the purpose of this paper to introduce a method of testing for the variation of the reactance under conditions of saturation. The resulting curves are an indication of the extent that saturation in the stator iron affects the total armature leakage reactance.

Experimental Methods

Many methods have been suggested for testing either an induction motor or a synchronous machine for armature leakage reactance. Few of these have been consistent with the definitions existent at the time, and only one corresponds to the present definitions. Rushmore[11] suggested, in 1904, that the leakage reactance of an alternator could be measured easily if the rotor of the machine could be removed and the terminal quantities used. This procedure is not exact, for the reactance thus determined includes not only the armature leakage reactance but the reactance of armature reaction produced by the magnetic flux in the air core of the machine. The air core flux, although it is much smaller than that existing when the rotor is in place, may not be neglected, because it may generate a reactive voltage equal to or greater than that produced by the leakage flux.

Modifications of Rushmore's method, suggested by Schenkel,[12] 1910, and by Roth,[13] 1925, have led to a procedure that is in agreement with the present definition. Briefly, the modifications consist of placing a rectangular test coil in the machine bore, one side equal to the stacking length and the other side equal to the machine diameter less the 2 air gaps. A 3-phase voltage, of sufficient magnitude to cause rated current to flow in the windings, is applied to the armature. The current, voltage, and power input to the armature are measured, as well as the voltage generated in the test coil. From these data the effective resistance drop and the voltage due to the bore flux are calculated and subtracted vectorially (figure 1) from the terminal voltage, leaving the armature leakage reactance drop. This method subtracts from the total reactive voltage only that due to the space fundamental component of flux crossing the air gap, and the results, therefore, correspond to the definition above.

If instead of measuring or calculating the armature reaction flux in the bore of the machine, a thick copper cylinder equal in length to the stacking length of the armature is placed in the machine, the eddy currents induced in it due to the 3-phase magnetomotive force of the armature will oppose the bore flux, leaving only the leakage reactance flux. The terminal quantities, voltage, current, and power, will then give directly the leakage reactance of the armature. This method is applicable only to small machines, since a copper cylinder for a large machine is prohibitive economically. A thin copper cylinder may be employed provided the frequency of the supply is raised to increase the effectiveness of the shielding. However, for very high frequencies there will be additional shielding in the iron of the machine that will decrease the slot and differential components, introducing errors in the results.

From time to time the suggestion has been made that armature leakage reactance could be determined directly from an analysis of the air-gap flux wave under conditions of sustained 3-phase short circuit. The fundamental component of flux so

Table I—Armature Leakage Reactance, 7.5 Kva Alternator

Test Determinations	
Air core without test coil	0.1621
Air core with test coil	0.0923
Copper cylinder	
60 cycles 3 phase with test coil	0.0992
120 cycles 3 phase with test coil	0.0949
60 cycles 1 phase with test coil	0.0904
Zero power factor	
Unsaturated	0.0935
Twice rated voltage (saturated)	0.0892
Other methods	
Static counter-magnetomotive force	0.0907
Copper sheet shielding	0.0933
Calculated Values	
Alger	0.0837
Kilgore	0.0775

obtained is to be considered as that flux effective in forcing the short-circuit current through the armature against the resistance and the leakage reactance.

All of these methods give values of armature leakage reactance obtained well below the break in the saturation curve, and it is impractical to extend any one of them into the region of saturation because of armature heating due to the high currents. In order to include the effect of saturation upon the armature leakage reactance it is necessary to determine values of that reactance under actual conditions of operation.

The definition of armature leakage reactance suggests a method of test that not only may be applied to the unsaturated machine but may be extended into the region of high saturation. If a test coil may be placed on the armature surface spanning a pole pitch and including only the stacking length, the voltage induced in it will include that due to the space fundamental of flux and that due to the space harmonics caused by irregularities in the main field, such as those due to the pole form and to amortisseur slots.

At zero power factor there will be no distortion in the main field due to any angular displacement between the armature magnetomotive force and the main field magnetomotive force. If the harmonics due to the amortisseurs are less than 10 per cent of the fundamental, the voltage measured by the test coil will be practically the same as that generated by the space fundamental of the air gap flux. The vector difference between the air gap voltage and the terminal voltage plus the armature resistance drop, will be the voltage due to the armature leakage reactance. However, since in this case the resistance drop is perpendicular to the terminal voltage, the algebraic difference between the air gap voltage and the terminal voltage may be taken, for practical purposes, to give the armature leakage reactance drop. In other words, the difference between the voltage induced in the test coil at no-load and that

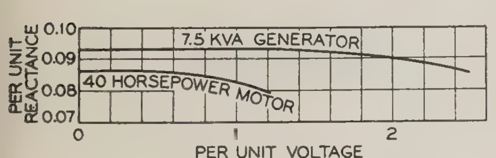


Fig. 3. Armature leakage reactance versus voltage, for the 2 machines

for full load current, zero power factor, taken as a ratio of the no-load value is the leakage reactance drop as a decimal fraction of the no-load voltage. This procedure may be repeated for voltages above and below the rated value to obtain a curve of armature leakage reactance as a function of voltage.

Experimental Results

The investigation on armature leakage reactance was centered about 2 machines, one an alternator rated at 7.5 kva, 220 volts, 19.7 amperes, 1,200 rpm, 60 cycles, and the other a synchronous motor rated at 40 horsepower, 440 volts, 44.5 amperes, 1,200 rpm,

Table II—Armature Leakage Reactance, 40 Horsepower Motor

Test Determinations	
Zero power factor	
Unsaturated	0.0860
Rated voltage (saturated)	0.0835
Other methods	
Static counter-magnetomotive force	0.0852
Copper sheet shielding	0.0833 direct axis
	0.0803 quadrature axis
Calculated Values	
Alger	0.0861
Kilgore	0.0824

60 cycles. The saturation curves for these machines (figure 2) indicate that they are admirably adapted to a study on the effect of saturation upon armature leakage reactance. The machines also differed somewhat in other respects; in the 7.5-kva alternator, the stacking length was equal to the inner radius of the stator, and the armature winding was 2-circuit, full pitch; in the 40 horsepower motor, the stacking length was 45 per cent of the inner stator radius, and the armature winding was single circuit, 75 per cent pitch. In both machines the straight portion of the end turns was very small, and the end connections were formed at an angle much less than the conventional 60 degrees, actually 51 degrees for the 40 horsepower motor and 50 degrees for the 7.5 kva generator.

It was impossible to remove the rotor from the 40 horsepower motor as the machine constituted one unit of a semi-permanent set. On the other hand, the 7.5 kva generator allowed of easy dismantling, and those methods applicable to the stator windings alone were tried on this machine.

The results of both the air-core method and that of using the copper cylinder are shown in table I. It is apparent both from physical considerations and from the test data, that neglect of the air core flux introduces large errors. The effect of increased shielding at higher frequencies is also indicated by the results at 60 and 120 cycles. Both of these methods serve as an indication of the unsaturated value of reactance, and while they may not be extended into the saturated region the values obtained are the limiting points that a curve of reactance as a function of voltage will approach with decreasing voltage.

The results of the zero power-factor method as applied to the 2 machines are given in figure 3. Both curves are flat over the region in which the machines are unsaturated, but the reactance decreases with increasing saturation. The decrease in reactance is due to a decreased leakage flux per ampere in the various leakage paths in the stator iron, the major portion occurring in the stator teeth.

In all of the past discussions on armature leakage reactance, in its application to synchronous machine operation, it has been customary to neglect completely the effect of saturation on this reactance, or to state that it is unaffected by saturation. The effect is not too great and for many problems may be neglected. However, with increasing refinements in the treatment on synchronous machines it is necessary at times to consider the effect of saturation on

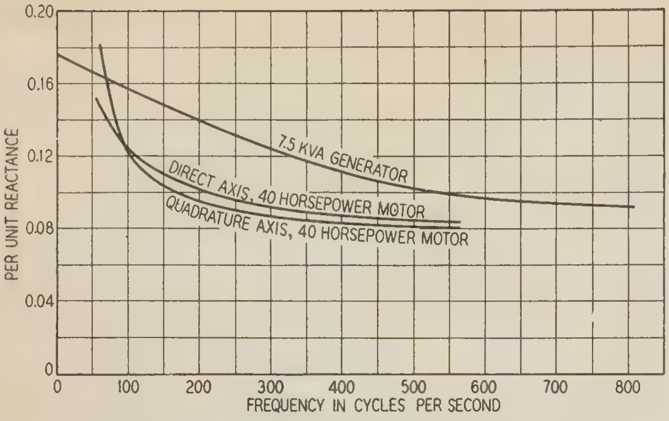


Fig. 4. Variation of reactance with frequency for the 2 machines, each with thin copper sheet in air-gap

all of the reactances, including armature leakage reactance.

Additional Test Methods

Two other test procedures have been devised to determine armature leakage reactance, which, while not consistent with the definition of the reactance, serve to indicate the approximate limiting values that it may have. The methods are presented here because of the consistent results obtained from their application to the 2 machines under consideration.

In one method, the machine rotor is so oriented that the pole axis is in line with the magnetomotive force axis on the armature, the armature magnetomotive force being produced by a single phase voltage applied to the terminals. A test coil, identical in shape with the armature coil, is fastened to the stator surface so that the coil sides are midway between the poles, and the end turns follow the contour of the armature winding end turns. Single phase voltage is then applied to both the stator and the rotor circuits and adjusted in magnitude and phase until there is zero voltage generated in the test coil on the armature surface.

Zero voltage in the test coil indicates that there is no space fundamental of flux crossing the air gap and that the flux produced by the armature current may be considered as leakage flux. This leakage flux is not the same as that defined as armature leakage flux for the synchronous machine because there are greater components of the space harmonics present within the stacking length, and a smaller component of armature reaction flux in the end turns. In application, this method requires considerable apparatus that is not required for the other methods, and the test technique is not so simple. The results are shown in tables I and II.

The other method consists in placing thin copper sheeting around the air gap of the machine, the copper sheeting extending out to the plane of the end turns, and applying a single phase source of variable frequency voltage to the armature terminals. The curve of equivalent 60 cycle reactance for the 7.5 kva machine is shown in the upper curve of figure 4 and indicates that the armature reaction flux within the stacking length decreases as the frequency increases, but does not go to zero because the thickness of copper is not sufficient for complete shielding. The increase in reactance due to the remaining armature reaction flux within the stacking length is offset by a decrease in the end turn flux due to the adjacent copper. The 2 effects tend to counterbalance each other at the higher frequencies, as indicated by the flattening out of the reactance curve for values above 500 cycles.

The results obtained on the 40 horsepower motor (the 2 lower curves of figure 4) are similar, even though the rotor was in place. Both curves of subtransient reactance drop to approximately the same value at higher frequencies.

Summary

Because armature leakage reactance is not a specific quantity, measurable directly as an overall effect, there have been many test methods suggested to determine approximate values of it. The most notable is that suggested by Potier,[14] in 1900, to aid in determining alternator regulation. It was soon recognized that the reactance obtained by the Potier method contained not only armature leakage reactance but a large component of field pole leakage as well. The Potier reactance, because of its simplicity of test determination, has maintained its place in the literature and has only recently[15] been modified to give a reactance which in the limit approaches very closely the calculated values of armature leakage reactance. It is impossible, even with the recently proposed modifications of Potier reactance, to determine the variation in armature leakage reactance because of the large masking effect of the pole leakage. The method proposed here makes possible a direct determination of the leakage reactance drop, and as a consequence small variations in this quantity due to an increased voltage may be detected.

While the other methods discussed do not indicate saturated values of the reactance, they serve as additional confirmation of the projected value of the curve found by the zero power-factor method. This was considered important at the beginning of the investigation, as the zero power-factor method involved a small difference between 2 relatively large quantities and there was some doubt as to the accuracy obtainable. As the experimental work progressed, it was found that very little difficulty was encountered due to this cause, for a curve of this difference as a function of armature current at constant terminal voltage gave a straight line having practically the same value of reactance for both the over-excited and the under-excited machine.

The saturated value of armature leakage reactance together with the effective armature resistance make possible a more exact determination of the air gap voltage under all conditions of loading. The air gap voltage in turn determines not only the saturated values of the synchronous reactances but also the additional field ampere-turns necessary to account for both the stator and rotor iron saturation. The field excitation amperes and the torque-angle of the loaded machine, both being of considerable im-

portance in system stability calculations, are obtained as the results of the calculations.

References

1. The Leakage Reactance of Induction Motors, C. A. Adams. *Trans.* of Intern. Elec. Cong., St. Louis, Mo., 1904, v. 1, p. 729.

2. Self-Starting Synchronous Motors, C. J. Fechheimer. A.I.E.E. Trans., v. 31, part 1, 1912, p. 529–85.

3. The Transient Reactions of Alternators, W. A. Durgin and R. H. Whitehead. A.I.E.E. Trans., v. 31, part 2, 1912, p. 1657–80.

4. Reactance of Synchronous Machines and Its Applications, R. E. Doherty and O. E. Shirley. A.I.E.E. Trans., v. 37, part 2, 1918, p. 1209–97.

5. Synchronous Machines I—An Extension of Blondel's Theory, R. E. Doherty and C. A. Nickle. A.I.E.E. Trans., v. 45, 1926, p. 912–42.

6. The Calculation of the Reactance of Synchronous Machines, P. L. Alger. A.I.E.E. Trans., v. 47, Apr. 1928, p. 493–513.

7. Calculation of Synchronous Machine Constants, L. A. Kilgore. A.I.E.E. Trans., v. 50, Dec. 1931, p. 1201–13.

8. Ueber die Ursachen der Funkenbildung an Kollektor und Bürsten bie Gleichstromdynamos, E. Dick. *E. T. Z.*, v. 19, 1898, p. 850.

9. Ueber die Funkenbildung an Gleichstrommaschinen, J. Fischer-Hinnen. *E. T. Z.*, v. 19, 1898, p. 850.

10. Equivalent Reactance of Synchronous Machines, S. B. Crary, L. A. March, and L. P. Shildneck. Elec. Engg. (A.I.E.E. Trans.), v. 53, Jan. 1934, p. 124–32.

11. The Regulation of Alternators, D. B. Rushmore. *Trans.* of Intern. Elec. Cong., St. Louis, Mo., 1904, v. 1, p. 729.

12. Determination of Leakage Flux on an Alternating-Current Machine, M. Schenkel. *E. u. M.*, v. 27, 1909, p. 201–8. See also *Electrician* (London), v. 63, 1909, p. 595 (abstract).

13. Critique des Quelques Methodes de Mesure de la Reactance due aux Fuites de l'Induit des Machines Electriques Relatives a Courants Alternatifs, E. Roth. *R. G. E.*, v. 17, 1925, p. 217–24.

14. Sur la Reaction d'Induit des Alternateurs, A. Potier. *l'Eclairage Electrique*, v. 24, no. 30, July 28, 1900.

15. Armature Leakage Reactance of Synchronous Machines, L. A. March and S. B. Crary. Elec. Engg. (A.I.E.E. Trans.), v. 54, Apr. 1935, p. 378–81.

Tests on Armature Resistance of Synchronous Machines

Armature resistance of synchronous machines, although usually disregarded when making torque-angle and excitation calculations, must be taken into account when making an accurate analysis. Values of armature resistance obtained in a series of tests are presented in this paper, which is a companion paper to "Test Values of Armature Leakage Reactance" in this issue, pages 700–5. Discussion of test methods, the effect of pole form on losses, and the use of effective armature resistance in determining the vector diagram of the machine are included herein.

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Although it was known very early in the history of synchronous machines that the apparent resistance of the armature did not agree with the d-c resistance, but was always greater in magnitude, little information is available on it from the practical standpoint. In most analyses on synchronous machines it has been customary for many years to disregard armature resistance upon the assumption that its magnitude is very small in comparison with the machine reactances, and hence will not appreciably alter results obtained by neglecting it. Such an approximation may be permissible for some machines, or for certain investigations where qualitative results only are desired. However, in many instances, particularly those involving detailed analyses, and those treating with machines of rather small ratings, armature resistance must be taken into account.

It is the aim of this paper to present some test results on armature resistance of synchronous machines. The paper includes a discussion on methods of test, the effect of pole form on additional losses, and the application of effective armature resistance in the vector diagram for the unsaturated synchronous machine operating under steady state conditions. The test results indicate that the effective armature resistance is independent of saturation.

Nature of Effective Armature Resistance

Resistance, as usually defined in d-c work, is the ratio of the voltage consumed by that part of the circuit under consideration to the current passing through that part of the circuit. This is called the true ohmic resistance. In a-c circuits this ratio gives the impedance rather than the resistance, hence a new definition is required. Resistance now becomes the ratio of the power expended in the circuit to the square of the current, a much broader definition.

For low frequency alternating currents in conductors surrounded by nonmagnetic materials, the conductors themselves being stranded, the resistance obtained by the second definition is the pure ohmic value, so far as can be determined. However, with increase in frequency, with massive conductors having no stranding, and with increased magnetic permeability of the medium surrounding the conductors, the apparent resistance of the circuit obtained by the second definition becomes greater than the true

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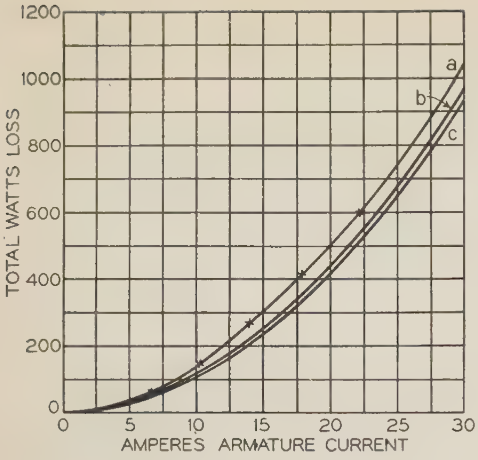


Fig. 1. Resistance loss curves for the salient pole machine

a. From dynamometer and V-curve tests; crosses show air-core measurements

b. Short-circuit core loss

c. Calculated from d-c resistance

ohmic resistance. Higher frequencies produce the phenomenon of skin effect which is of decided importance in a few rotating machines.

In the synchronous machine, as with all rotating apparatus, the armature copper is embedded in iron. The slots are relatively narrow and extend rather deeply into the magnetic body, due to practical design methods which call for double layer windings and a vertical arrangement of the conductors. Considerable flux therefore surrounds the conductors when carrying current, its effect being observed in several ways. It produces the slot leakage reactance as a consequence, it creates skin effect, and it aids in giving rise to eddy currents with their attending losses. A 60 cycle current in solid copper may induce eddy currents of a very harmful nature and greatly magnify the heating over that calculated by using the pure ohmic resistance.

It is thus observed that not only is power expended in the armature conductors due to the ohmic resistance, but also in them because of eddy currents set up by induction of the flux produced by the load current, and in addition outside of the copper by induction currents and some hysteresis by this localized flux. Differential leakage flux produces further losses, in the pole faces, that are proportional to the square of the armature current and are therefore chargeable to the armature as an increased resistance. These secondary losses are dependent upon the magnitude of the current, and give rise to the concept of *effective resistance.* Briefly defined, the effective resistance of an a-c circuit is that resistance which when multiplied by the square of the current will give the total losses attending that current, the ohmic resistance loss plus the secondary losses of eddy currents, hysteresis, etc., caused by its changing flux.

To reduce the effective resistance as much as possible, and to minimize heating effects, armature conductors are stranded, and often transposed. About $^3/_8$ of an inch is the usual design limit on the height of any single strand in the slot. Stranding eliminates much of the eddy current loss that otherwise would be obtained, but even at that the effective resistance yet may be considerably greater than the ohmic value. Arnold[1] has stated that the effective resistance of a 3-phase machine may be from 1.3 to 2.0 times the ohmic resistance, but present practice when considering it is to use a factor of from 1.1 to perhaps 1.5.

The d-c resistance of the armature copper may be calculated easily by usual methods, but the attending strand losses, and the core losses produced by eddy currents in the windings and in the iron, cannot be obtained so readily. They form the so-called load losses[2] which very often are assumed to be a given percentage of the machine rating. Some proposals have been made now and then for calculating them, or at least part of them, but the results do not appear in general use in the practicing field. The strand loss component has been given most attention in the past, and is probably the one most open to quantitative analysis, but to the writer's knowledge there is no method for determining the iron loss portion.

Methods of Test

It was shown very early by Steinmetz,[3] in his studies on the synchronous machine, that the power output of the motor is the armature input minus the sum of stator copper, windage and friction, core, and excitation (for direct connected exciter) losses. That is,

$$\text{power output} = \text{stator input} - \text{stator } i^2r - (\text{windage and friction} + \text{core loss} + \text{excitation loss}) \quad (1)$$

Upon the assumption that the group of losses enclosed in the parentheses is constant, it follows that any variation in the total losses under load then is included in the stator copper loss, the d-c resistance being modified accordingly. Hence,

$$P = ei \cos \theta - i^2r - \text{constant losses} \quad (2)$$

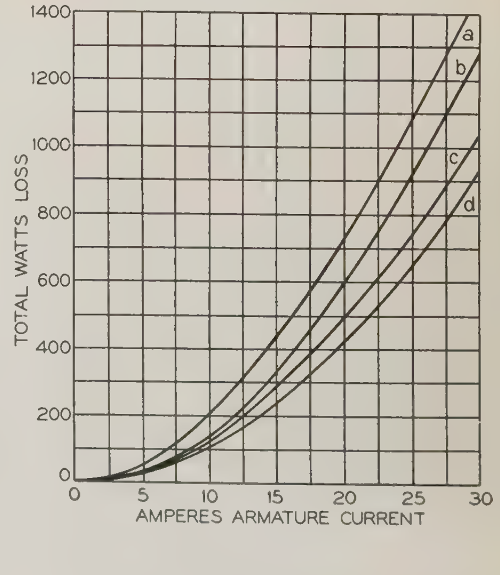
The assumption with respect to the so-called constant losses is carried out in practice with the exception that the internal voltage is determined by correcting the terminal voltage for the resistance drop.

For the generator, similar relations may be written:

$$\begin{aligned}\text{shaft input} - \text{constant losses} &= \text{stator output} + i^2r \\ &= -\text{terminal input} + i^2r \end{aligned} \quad (3)$$

If the shaft input is maintained equal to the constant

Fig. 2. Resistance loss curves for the cylindrical rotor machine



a. Dynamometer and V-curve tests
b. Short-circuit core loss
c. Air-core and salient pole effective resistance
d. Calculated from d-c resistance

1. For all numbered references see list at end of paper.

losses existing for zero armature current at the desired excitation, all i^2r losses then are supplied from the a-c lines as implied from the last equation.

This relation has suggested a method of test for effective armature resistance. The constant losses are supplied by an auxiliary driver and held at the value found under the conditions of the required a-c voltage with no power exchange between the a-c machine and its supply system. The excitation of the a-c machine then is varied, causing circulating current to flow, the effective resistance per leg of the a-c machine being given by the ratio of the a-c power input to 3 times the square of the current.

A variation of the foregoing method of test, and one which is quite practical, is that of measuring the machine input when it is operated as a motor under the conditions for the V-curve determination. In this case the wattmeters read also the constant losses. These losses are determined at unity power factor, i. e., minimum armature current, and are subtracted from the total power found for given values of circulating current. Obviously, these 2 methods of test give the same results, the only difference in calculating the resistance being the subtraction of the no-load wattmeter readings in the case of the V-curve test.

The methods involving resistance determination from circulating currents lead to the approximate measurement of resistance under conditions of short circuit. Results obtained from the short-circuit test of necessity will be lower than those found under the other methods just described because in this last case the flux in the machine is very low.

The method of test in which the rotor of the machine is removed[4] may be used at times to give approximate results on effective armature resistance. However, the method neglects the construction of the rotor, and is applicable only to machines having air-gap wave shapes which are purely sinusoidal.

An objection to the first method of test is that there is required an auxiliary machine to drive the alternator, the input to the driver to be held constant. If the machine is a dynamometer the torque arm must be kept in balance. For the V-curve method the synchronous machine runs as a motor, and if amortisseur windings are not present an auxiliary motor is needed to bring the test machine up to speed. Insufficient damping action of the secondary rotor circuits may lead to hunting, but this effect may be reduced greatly by inserting reactances in the supply lines. Both methods may involve somewhat small differences between fairly large wattmeter readings, but no difficulty was experienced in this respect in any of the runs, nor was there any trouble in reading the no-load input to the machine under the V-curve method of test. Wattmeters designed for ordinary power factors were used, in that the 2-wattmeter method of power measurement limits the angle for the wattmeters to 60 degrees, a power factor angle which is not too low. Limitations on the short-circuit method are the requirement of a dynamometer or a calibrated driver, and the low flux within the machine which leads to results below those for the first 2 methods. The air-core manner of test is practicable only during construction of the machine, or when the rotor may be removed easily. Practically, the V-curve test is to be recommended.

Fig. 4. No-load air-gap wave shape for the cylindrical rotor machine showing harmonics due to rotor teeth

Fig. 3. No-load air-gap wave shape for the salient pole machine

Test Results

The results of these various methods of test are shown in figures 1 and 2, together with the loss curves calculated from the d-c resistance. The test data were taken on a 7.5-kva 220-volt 1,200-rpm experimental alternator having 2 rotors, one a salient pole rotor and the other a wound rotor which carried direct current in the windings to make of it a cylindrical rotor machine.

Figure 1, which gives the loss curves for the salient pole machine, shows the deviations between the results obtained by the described test methods. Curve a is that for both the dynamometer and V-curve runs, the data from these methods giving exactly the same smooth curve. The crosses show the loss measurements for the air-core test, the points also falling on curve a. Curve b, for the short-circuit test, lies below, as it should, and is closer to the d-c resistance calculations than to curve a.

At normal current of 19.7 amperes the d-c armature resistance increases 22.2 per cent to give the effective armature resistance, a representative increase for a machine of this size. It will be observed that the difference between the d-c and effective armature resistance losses appears not to change very greatly from approximately normal current to 150 per cent of normal value. Measurements were taken on the machine for several conditions of terminal voltage, from half voltage to $2^1/_2$ times rated value at which the iron magnetomotive force is 30 per cent of the air-gap magnetomotive force, but no discernible variation was found in the resistance loss curve. Furthermore, over-excitation and under-excitation also gave no apparent deviations, hence

curve a represents the single result of the many runs.

Figure 2, for the cylindrical rotor machine, shows an effective armature resistance of approximately 175 per cent of the d-c resistance, at rated current. Again, both dynamometer and V-curve measurements produced the same results, curve a. In this case, however, the curve obtained from the short-circuit test lies closer to that for the effective resistance, the reason for this fact, and for the much higher resistance loss of the cylindrical rotor machine, lying in the form of the air-gap wave shape. Whereas the air-gap wave shape for the salient pole machine is smooth and close to a sine wave, as shown by figure 3, the air-gap wave shape for the cylindrical rotor machine has a high harmonic content, figure 4. These harmonics are due to the rotor teeth. Again, it was not found that voltage or change in excitation gave measurable deviations from a single curve.

Table I—Comparison Between Calculated and Test Values of Torque-Angle and Excitation for the Salient Pole Machine

e_t Volts	i_{avg} Amperes	W_1 Watts	W_2 Watts	Angle, Degrees Calc.	Angle, Degrees Test	I_f Amperes Calc.	I_f Amperes Test
Motor, 0.8 Power Factor Lagging							
220	0.0	0	0	0.0	0.0	3.37	3.37
220	5.15	460	1,120	5.2	5.2	2.83	2.85
220	10.75	920	2,330	12.4	12.2	2.45	2.44
220	15.2	1,255	3,320	18.5	18.5	2.22	2.18
220	19.9	1,730	4,345	26.8	26.4	2.19	2.14
220	24.15	2,135	5,280	34.7	34.5	2.27	2.23
220	29.7	2,570	6,480	45.0	44.5	2.57	2.43
Motor, 0.8 Power Factor Leading							
220	0.0	0	0	0.0	0.0	3.37	3.37
220	4.60	1,060	420	5.2	5.4	3.75	3.70
220	11.2	2,480	980	11.8	11.7	4.37	4.33
220	16.0	3,625	1,425	15.7	16.0	4.93	4.92
220	19.1	4,270	1,680	18.0	18.0	5.28	5.25
220	23.6	5,280	2,090	21.0	21.2	5.82	5.81
220	30.1	6,780	2,710	25.0	25.5	6.59	6.58
220	40.0	8,950	3,550	30.0	30.5	7.94	7.90

W_1 and W_2 are the wattmeter readings in the 2-wattmeter method of measuring 3 phase power

The 3 major factors contributing to harmonics in the air-gap wave shape are armature reaction, pole form, and the presence of slots for windings or amortisseurs in the pole faces. All of the above tests were made at zero power factor, hence any distortion in the main flux wave due to armature reaction was a minimum. At other than zero power factor, harmonics caused by armature reaction are present, and for this reason zero power factor tests may not be exactly comparable to actual load conditions. In spite of this, it is believed that the results presented here indicate very closely the actual conditions.

Harmonics in the no-load flux wave, introduced by pole form, will be present in all load conditions, although their magnitudes may change somewhat. These harmonics are productive of additional armature losses. In the same way, slots in the rotor, either for the d-c field winding, or for pole face windings, may give harmonics of relatively high frequency and of considerable magnitude.

The salient pole machine had a smooth pole face and was of such a shape that the no-load flux wave had no appreciable harmonic content. Under all conditions of load the wave shape remained smooth even though distortion due to armature reaction was present. The result of such a wave shape is not to increase additional armature losses to a very high percentage of the d-c resistance losses. On the other hand, the cylindrical rotor machine had 9 rotor slots per pole, thus introducing the 9th harmonic in the air-gap wave shape. Its magnitude was about 25 per cent of the fundamental. The increase in armature losses is evident from figure 2. Slots for amortisseurs give similar results.

Application

The application toward which this work has been pointed is a more exact determination of torque-angle and excitation of the synchronous machine. It has been general practice in most treatments on such machines to neglect armature resistance entirely, this forming one of the assumptions in the analyses. For many machines the assumption of zero resistance is justifiable, at least where approximate or qualitative results only are desired, or for many large machines where resistance is relatively small and neglect of it will not introduce any serious errors. On the other hand, for many machines, particularly smaller ones, the resistance drop may be an appreciable percentage of rated voltage, in which case it must be considered, in order to obtain correct results.

To show the agreement between calculated and test data when armature resistance is taken into account, tables I and II are given. The data were obtained under conditions of no saturation. It will be observed that the agreement between calculation and test is very good, indicating the accuracy obtained when the effect of resistance is included in the vector diagram. Load tests were taken on these machines at various other values of power factor than the ones presented here, similar good agreement between calculation and test being found. The writer does not recall having seen tabular data of

Table II—Comparison Between Calculated and Test Values of Torque-Angle and Excitation for the Cylindrical Rotor Machine

e_t Volts	$i_{avg.}$ Amperes	W_1 Watts	W_2 Watts	Angle, Degrees Calc.	Angle, Degrees Test	I_f Amperes Calc.	I_f Amperes Test
Motor, Unity Power Factor							
220	0.0	0	0	0.0	0.0	26.7	26.7
220	3.90	744	744	30.2	30.5	29.8	29.6
220	7.95	1,515	1,515	50.8	51.5	39.1	39.0
220	12.40	2,365	2,365	63.0	63.5	52.8	52.2
220	16.00	3,045	3,045	68.9	70.0	65.7	65.1
220	20.05	3,910	3,910	73.4	74.5	80.7	80.0
Motor, 0.8 Power Factor Leading							
220	0.0	0	0	0.0	0.0	26.7	26.7
220	4.23	960	360	20.7	21.0	38.9	39.2
220	8.95	1,930	716	31.0	31.2	54.7	54.5
220	13.30	2,880	1,080	36.9	37.2	70.5	70.3
220	18.30	4,000	1,585	41.3	41.5	89.4	89.3

(See footnote of table I.)

this kind presented before to show the relation of actual machine performance to the theory of its steady state operation as given by the complete vector diagram. The additional losses occurring under load, and chargeable to the armature, properly should be included in the vector diagram. The power-angle equation for the synchronous machine does not include constant losses but does take into account all i^2r effects, hence the vector diagram method of determining machine performance should consider the same losses, these to include the d-c resistance and all load losses. The vector diagram is directly related to the power-angle equation.

Physically, resistance connotes a loss of power. For the generator, it means that the power which crosses the air-gap is greater than the machine output, to the extent at least of the equivalent i^2r of the armature. In the motor, the terminal power is always greater than the air-gap power by the amount of the armature copper loss. Obviously, then, resistance will affect machine performance in the same general manner as will load impedance, and will require some changes in torque-angle and excitation over those which obtain for no resistance.

The effect of armature resistance in altering torque-angle and in changing excitation requirements depends largely upon the power factor. In a general way, resistance increases the angle and decreases the excitation for the unity power factor and over-excited synchronous motor, and decreases the angle and increases the excitation for the under-excited motor. The converse statements apply to the generator. With constant terminal voltage and excitation, increase in resistance results in a greater torque-angle for either generator or motor action. Resistance has a greater effect, by way of a greater angle, for the motor than for the generator, the reason lying in the fact that in the first case the ir drop is subtractive with respect to the terminal voltage, and in the second case is additive.

Summary

Armature resistance may have an appreciable effect upon the torque-angle and excitation of the synchronous machine operating under steady state conditions of loading. In general, it must be taken into account when accuracy of calculation is desired. Certainly, the exact effects of armature resistance must be known for the unsaturated machine before the saturated machine can be treated correctly, because resistance influences the air gap voltage as well as does armature leakage reactance. Neglect of the effective resistance may lead to large errors in the corrections for saturation.

The effective resistance of a synchronous machine may be obtained practically from wattmeter readings while the machine is run as for the V-curve determination. For a normally designed machine having a smooth air-gap voltage wave shape, the effective resistance will not increase greatly over the d-c resistance of the armature, but may be from perhaps 15 to 30 per cent higher in magnitude. Slots in the rotor, such as induction motor slots or slots for pole face windings, produce harmonics which increase greatly the apparent armature resistance. The losses caused by the harmonics may be several times the increased losses created otherwise, and it is possible for some machines to show an effective resistance of 2 or more times the d-c resistance. From the data presented it appears that saturation does not influence effective armature resistance to a determinable degree, or that under-excitation gives results which differ in recognizable amounts from conditions of over-excitation.

References

1. Die Wechselstromtechnik, E. Arnold. (A book.) V. 4, 1913, Julius Springer, Berlin.

2. A Comparison of the Efficiency of Synchronous Machines as Determined by Various Methods, P. L. Alger. *G. E. Rev.*, v. 29, Nov. 1926, p. 765–74.

3. Alternating Current Phenomena, C. P. Steinmetz. (A book.) 1897, McGraw-Hill Book Company, New York, N. Y.

4. A Contribution to Research on the Experimental Determination of the Losses in Alternators, E. Roth. A.I.E.E. Jl., v. 45, May 1926, p. 422–9.

Elliptic Integrals of Large Moduli

Tables of complete elliptic integrals of the first kind for large moduli are presented in this paper. While elliptic integrals are used in various kinds of engineering work, these tables are particularly useful in calculating mutual and self-inductances of cylindrical coils.

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COMPLETE elliptic integrals often are used in electrical engineering problems, as well as in other types of work. For example, in chapter III of reference 1 (see list at end of paper) are 9 formulas for the magnetic field of a cylindrical coil and 1 for the force between coils involving these quantities. Also, in reference 2 are 3 formulas for self-inductance of coils and 10 for mutual inductance

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Table I—Values of $K/\log_e(4 \sec \Theta)$

Θ 86 Deg Min	$\frac{K}{\log_e(4 \sec \Theta)}$	Difference	Θ 87 Deg Min	$\frac{K}{\log_e(4 \sec \Theta)}$	Difference	Θ 88 Deg Min	$\frac{K}{\log_e(4 \sec \Theta)}$	Difference	Θ 89 Deg Min	$\frac{K}{\log_e(4 \sec \Theta)}$	Difference
0	1.000 918 4	−73	0	1.000 527 6	−56	0	1.000 240 4	− 38	0	1.000 062 15	− 202
1	1.000 911 1	−73	1	1.000 522 0	−56	1	1.000 236 6	− 39	1	1.000 060 13	− 198
2	1.000 903 8	−73	2	1.000 516 4	−56	2	1.000 232 7	− 38	2	1.000 058 15	− 195
3	1.000 896 5	−73	3	1.000 510 8	−56	3	1.000 228 9	− 38	3	1.000 056 20	− 191
4	1.000 889 2	−72	4	1.000 505 2	−55	4	1.000 225 1	− 38	4	1.000 054 29	− 189
5	1.000 882 0	−72	5	1.000 499 7	−55	5	1.000 221 3	− 37	5	1.000 052 40	− 185
6	1.000 874 8	−72	6	1.000 494 2	−55	6	1.000 217 6	− 37	6	1.000 050 55	− 182
7	1.000 867 6	−71	7	1.000 488 7	−55	7	1.000 213 9	− 37	7	1.000 048 73	− 178
8	1.000 860 5	−71	8	1.000 483 2	−54	8	1.000 210 2	− 36	8	1.000 046 95	− 176
9	1.000 853 4	−71	9	1.000 477 8	−54	9	1.000 206 6	− 36	9	1.000 045 19	− 172
10	1.000 846 3	−71	10	1.000 472 4	−53	10	1.000 203 0	− 36	10	1.000 043 47	− 169
11	1.000 839 2	−70	11	1.000 467 1	−54	11	1.000 199 4	− 35	11	1.000 041 78	− 165
12	1.000 832 2	−70	12	1.000 461 7	−53	12	1.000 195 9	− 35	12	1.000 040 13	− 163
13	1.000 825 2	−70	13	1.000 456 4	−52	13	1.000 192 4	− 35	13	1.000 038 50	− 159
14	1.000 818 2	−69	14	1.000 451 2	−53	14	1.000 188 9	− 35	14	1.000 036 91	− 156
15	1.000 811 3	−70	15	1.000 445 9	−52	15	1.000 185 4	− 34	15	1.000 035 35	− 152
16	1.000 804 3	−69	16	1.000 440 7	−52	16	1.000 182 0	− 34	16	1.000 033 83	− 150
17	1.000 797 4	−68	17	1.000 435 5	−51	17	1.000 178 6	− 34	17	1.000 032 33	− 146
18	1.000 790 6	−69	18	1.000 430 4	−52	18	1.000 175 2	− 33	18	1.000 030 87	− 142
19	1.000 783 7	−68	19	1.000 425 2	−51	19	1.000 171 9	− 33	19	1.000 029 45	− 140
20	1.000 776 9	−68	20	1.000 420 1	−50	20	1.000 168 6	− 33	20	1.000 028 05	− 136
21	1.000 770 1	−67	21	1.000 415 1	−51	21	1.000 165 3	− 32	21	1.000 026 69	− 133
22	1.000 763 4	−67	22	1.000 410 0	−50	22	1.000 162 1	− 32	22	1.000 025 36	− 129
23	1.000 756 7	−67	23	1.000 405 0	−50	23	1.000 158 9	− 32	23	1.000 024 07	− 127
24	1.000 750 0	−67	24	1.000 400 0	−49	24	1.000 155 7	− 31	24	1.000 022 80	− 122
25	1.000 743 3	−66	25	1.000 395 1	−49	25	1.000 152 6	− 32	25	1.000 021 58	− 120
26	1.000 736 7	−67	26	1.000 390 2	−49	26	1.000 149 4	− 30	26	1.000 020 38	− 116
27	1.000 730 0	−65	27	1.000 385 3	−49	27	1.000 146 4	− 31	27	1.000 019 22	− 113
28	1.000 723 5	−66	28	1.000 380 4	−48	28	1.000 143 3	− 30	28	1.000 018 09	− 110
29	1.000 716 9	−65	29	1.000 375 6	−48	29	1.000 140 3	− 30	29	1.000 016 99	− 106
30	1.000 710 4	−65	30	1.000 370 8	−48	30	1.000 137 3	− 30	30	1.000 015 93	− 103
31	1.000 703 9	−65	31	1.000 366 0	−47	31	1.000 134 3	− 29	31	1.000 014 90	− 99
32	1.000 697 4	−65	32	1.000 361 3	−48	32	1.000 131 4	− 29	32	1.000 013 91	− 96
33	1.000 690 9	−64	33	1.000 356 5	−47	33	1.000 128 5	− 29	33	1.000 012 95	− 93
34	1.000 684 5	−64	34	1.000 351 8	−46	34	1.000 125 6	− 28	34	1.000 012 02	− 89
35	1.000 678 1	−63	35	1.000 347 2	−46	35	1.000 122 8	− 28	35	1.000 011 13	− 86
36	1.000 671 8	−64	36	1.000 342 6	−46	36	1.000 120 0	− 28	36	1.000 010 27	− 83
37	1.000 665 4	−63	37	1.000 338 0	−46	37	1.000 117 2	− 27	37	1.000 009 440	− 792
38	1.000 659 1	−62	38	1.000 333 4	−45	38	1.000 114 5	− 27	38	1.000 008 648	− 758
39	1.000 652 9	−63	39	1.000 328 9	−46	39	1.000 111 8	− 27	39	1.000 007 890	− 724
40	1.000 646 6	−62	40	1.000 324 3	−44	40	1.000 109 1	− 27	40	1.000 007 166	− 689
41	1.000 640 4	−62	41	1.000 319 9	−45	41	1.000 106 4	− 26	41	1.000 006 477	− 656
42	1.000 634 2	−62	42	1.000 315 4	−44	42	1.000 103 8	− 26	42	1.000 005 821	− 621
43	1.000 628 0	−61	43	1.000 311 0	−44	43	1.000 101 2	− 25	43	1.000 005 200	− 586
44	1.000 621 9	−61	44	1.000 306 6	−44	44	1.000 098 69	−252	44	1.000 004 614	− 552
45	1.000 615 8	−61	45	1.000 302 2	−43	45	1.000 096 17	−249	45	1.000 004 062	− 518
46	1.000 609 7	−60	46	1.000 297 9	−43	46	1.000 093 68	−246	46	1.000 003 544	− 482
47	1.000 603 7	−61	47	1.000 293 6	−43	47	1.000 091 22	−243	47	1.000 003 062	− 448
48	1.000 597 6	−59	48	1.000 289 3	−42	48	1.000 088 79	−239	48	1.000 002 614	− 413
49	1.000 591 7	−60	49	1.000 285 1	−42	49	1.000 086 40	−237	49	1.000 002 201	− 378
50	1.000 585 7	−59	50	1.000 280 9	−42	50	1.000 084 03	−233	50	1.000 001 823	− 343
51	1.000 579 8	−60	51	1.000 276 7	−41	51	1.000 081 70	−230	51	1.000 001 480	− 308
52	1.000 573 8	−58	52	1.000 272 6	−42	52	1.000 079 40	−227	52	1.000 001 172	− 272
53	1.000 568 0	−59	53	1.000 268 4	−41	53	1.000 077 13	−224	53	1.000 000 899 9	−2368
54	1.000 562 1	−58	54	1.000 264 3	−40	54	1.000 074 89	−220	54	1.000 000 663 1	−2010
55	1.000 556 3	−58	55	1.000 260 3	−40	55	1.000 072 69	−217	55	1.000 000 462 1	−1652
56	1.000 550 5	−58	56	1.000 256 3	−40	56	1.000 070 52	−214	56	1.000 000 296 9	−1291
57	1.000 544 7	−57	57	1.000 252 3	−40	57	1.000 068 38	−211	57	1.000 000 167 8	− 928
58	1.000 539 0	−57	58	1.000 248 3	−40	58	1.000 066 27	−208	58	1.000 000 075 04	−5611
59	1.000 533 3	−57	59	1.000 244 3	−39	59	1.000 064 19	−204	59	1.000 000 018 93	−1893
									90 Deg	1.0	

of coils, which are in terms of complete elliptic integrals.

The usual way to obtain the values of these integrals is to use tables of them, but when the modulus becomes large, that is, when it approaches unity, the complete elliptic integral of the first kind, K, becomes large, approaching infinity, and the steps between the tabulated values are also large, making accurate interpolation difficult. This is stated on page 7 of reference 2 and it readily is experienced by anyone who uses the formulas for various shapes and positions of coils. Alternative formulas and series frequently are used to avoid this difficulty.

In this paper, 2 tables are given that are supplementary to those of Legendre which usually are used (see reference 3, volume 2, tables I and VIII). They are for the purpose of assisting in the determination of accurate values of the complete elliptic integral of the first kind,

$$K = \int_0^{\pi/2} \frac{d\phi}{\sqrt{(1 - \sin^2 \Theta \sin^2 \phi)}}$$

where the modulus is $\sin \Theta$, often denoted by k.

The tables are for values of θ from 86 to 90 degrees.

Values of K are given in table II for each minute of θ, while Legendre's table gives them, in the logarithmic form, for each 6 minutes. Even then, the steps in the one-minute table at 89 degrees 0 minutes are 1/320 and the last step of the table is 1/13.

It is well known that for values of θ nearly equal to 90 degrees, K can be expressed by a convergent series the first term of which is $\log_e (4 \sec \theta)$, where $\log_e$ denotes natural logarithm. This series was used for computing tables I and II. (See pages 46 and 54 of reference 4, and equation 3, page 8 of reference 2.) In table I are given values of $K/\log_e (4 \sec \theta)$. This table is much more precise than table II, the coarsest step being 1/136,000 at 86 degrees. Very complete tables are, of course, available for finding $\log_e \sec \theta$, the easiest method probably being to multiply the tabulated common logarithm of sec θ by 2.302 585. The addition of $\log_e 4 = 1.386\ 294$ can be made directly.

Then, multiplying the value of $\log_e (4 \sec \theta)$ by the tabulated quantity, which is slightly greater than unity, the precise value of K is found. The table is arranged equally well for multiplying by a calculating machine or by a logarithm table.

As an example of the use of table I, let θ = 89 degrees 0 minutes. Then

$$\log_e \sec \theta = 1.758\,1447 \times 2.302\,585 = 4.048\,28$$
$$\log_e 4 = 1.386\,29$$

$$\log_e (4 \sec \theta) = 5.434\,57$$

Multiplying by 1.000 062 15 from table I, the value of K, 5.434 91 is obtained, which agrees with the value in table II and with the value tabulated by Legendre.

In most practical cases, the precision of the result depends on how accurately θ or sec θ is known. If it be desired to obtain elliptic integrals to more decimal places than are given by logarithmic tables (tables giving 10 places are available), use may be made of series of which several types are available.

In preparing the tables, the computations were performed a second time to check their correctness. The computations were carried out to more decimal places than are tabulated here. Columns of second differences were made as an additional check on the accuracy.

Table II—Complete Elliptic Integrals of the First Kind, K

θ 86 Deg Min	K	Difference	θ 87 Deg Min	K	Difference	θ 88 Deg Min	K	Difference	θ 89 Deg Min	K	Difference
0	4.052 76	414	0	4.338 65	555	0	4.742 72	835	0	5.434 91	1680
1	4.056 90	416	1	4.344 20	557	1	4.751 07	842	1	5.451 71	1708
2	4.061 06	418	2	4.349 77	561	2	4.759 49	849	2	5.468 79	1738
3	4.065 24	420	3	4.355 38	564	3	4.767 98	856	3	5.486 17	1769
4	4.069 44	421	4	4.361 02	567	4	4.776 54	864	4	5.503 86	1800
5	4.073 65	423	5	4.366 69	571	5	4.785 18	871	5	5.521 86	1834
6	4.077 88	425	6	4.372 40	573	6	4.793 89	880	6	5.540 20	1868
7	4.082 13	427	7	4.378 13	578	7	4.802 69	887	7	5.558 88	1904
8	4.086 40	429	8	4.383 91	580	8	4.811 56	895	8	5.577 92	1941
9	4.090 69	431	9	4.389 71	584	9	4.820 51	903	9	5.597 33	1979
10	4.095 00	432	10	4.395 55	587	10	4.829 54	911	10	5.617 12	2019
11	4.099 32	435	11	4.401 42	591	11	4.838 65	920	11	5.637 31	2061
12	4.103 67	436	12	4.407 33	595	12	4.847 85	928	12	5.657 92	2105
13	4.108 03	438	13	4.413 28	598	13	4.857 13	937	13	5.678 97	2149
14	4.112 41	441	14	4.419 26	602	14	4.866 50	946	14	5.700 46	2197
15	4.116 82	442	15	4.425 28	605	15	4.875 96	956	15	5.722 43	2247
16	4.121 24	444	16	4.481 33	609	16	4.885 52	964	16	5.744 90	2298
17	4.125 68	447	17	4.437 42	613	17	4.895 16	974	17	5.767 88	2352
18	4.130 15	448	18	4.443 55	617	18	4.904 90	983	18	5.791 40	2409
19	4.134 63	450	19	4.449 72	620	19	4.914 73	994	19	5.815 49	2468
20	4.139 13	453	20	4.455 92	625	20	4.924 67	1003	20	5.840 17	2531
21	4.143 66	455	21	4.462 17	628	21	4.934 70	1014	21	5.865 48	2597
22	4.148 21	456	22	4.468 45	633	22	4.944 84	1023	22	5.891 45	2666
23	4.152 77	459	23	4.474 78	636	23	4.955 07	1035	23	5.918 11	2739
24	4.157 36	461	24	4.481 14	641	24	4.965 42	1046	24	5.945 50	2816
25	4.161 97	463	25	4.487 55	645	25	4.975 88	1056	25	5.973 66	2898
26	4.166 60	466	26	4.494 00	649	26	4.986 44	1068	26	6.002 64	2985
27	4.171 26	467	27	4.500 49	654	27	4.997 12	1079	27	6.032 49	3076
28	4.175 93	470	28	4.507 03	657	28	5.007 91	1092	28	6.063 25	3175
29	4.180 63	472	29	4.513 60	662	29	5.018 83	1103	29	6.095 00	3278
30	4.185 35	474	30	4.520 22	667	30	5.029 86	1116	30	6.127 78	3389
31	4.190 09	477	31	4.526 89	671	31	5.041 02	1128	31	6.161 67	3509
32	4.194 86	479	32	4.533 60	676	32	5.052 30	1142	32	6.196 76	3636
33	4.199 65	481	33	4.540 36	680	33	5.063 72	1154	33	6.233 12	3773
34	4.204 46	484	34	4.547 16	685	34	5.075 26	1168	34	6.270 85	3922
35	4.209 30	486	35	4.554 01	690	35	5.086 94	1182	35	6.310 07	4082
36	4.214 16	489	36	4.560 91	694	36	5.098 76	1196	36	6.350 89	4255
37	4.219 05	491	37	4.567 85	700	37	5.110 72	1211	37	6.393 44	4445
38	4.223 96	493	38	4.574 85	704	38	5.122 83	1225	38	6.437 89	4651
39	4.228 89	496	39	4.581 89	710	39	5.135 08	1241	39	6.484 40	4879
40	4.233 85	498	40	4.588 99	714	40	5.147 49	1257	40	6.533 19	5128
41	4.238 83	501	41	4.596 13	720	41	5.160 06	1272	41	6.584 47	5407
42	4.243 84	504	42	4.603 33	725	42	5.172 78	1289	42	6.638 54	5715
43	4.248 88	506	43	4.610 58	731	43	5.185 67	1306	43	6.695 69	6062
44	4.253 94	508	44	4.617 89	736	44	5.198 73	1323	44	6.756 31	6454
45	4.259 02	512	45	4.625 25	741	45	5.211 96	1341	45	6.820 85	6899
46	4.264 14	514	46	4.632 66	747	46	5.225 37	1359	46	6.889 84	7410
47	4.269 28	516	47	4.640 13	752	47	5.238 96	1378	47	6.963 94	8004
48	4.274 44	520	48	4.647 65	759	48	5.252 74	1397	48	7.043 98	8701
49	4.279 64	522	49	4.655 24	764	49	5.266 71	1417	49	7.130 99	9531
50	4.284 86	525	50	4.662 88	770	50	5.280 88	1438	50	7.226 30	10535
51	4.290 11	528	51	4.670 58	776	51	5.295 26	1459	51	7.331 65	11778
52	4.295 39	530	52	4.678 34	782	52	5.309 85	1480	52	7.449 43	13353
53	4.300 69	534	53	4.686 16	789	53	5.324 65	1502	53	7.582 96	15415
54	4.306 03	536	54	4.694 05	795	54	5.339 67	1526	54	7.737 11	18232
55	4.311 39	539	55	4.702 00	801	55	5.354 93	1549	55	7.919 43	22314
56	4.316 78	543	56	4.710 01	807	56	5.370 42	1574	56	8.142 57	28769
57	4.322 21	545	57	4.718 08	815	57	5.386 16	1598	57	8.430 26	40546
58	4.327 66	548	58	4.726 23	821	58	5.402 14	1625	58	8.835 72	69315
59	4.333 14	551	59	4.734 44	828	59	5.418 39	1652	59	9.528 87	
									90 Deg	∞	

References

1. A Treatise on the Theory of Alternating Currents, Alexander Russell, v. 1, second edition, Cambridge (Eng.) Univ. Press, 1914.

2. Scientific Paper 169, U.S. Bureau of Standards, E. B. Rosa and F. W. Grover.

3. Traitè des Fonctions Elliptiques, A. M. Legendre, Huzard-Courcier, Paris, 1825.

4. An Elementary Treatise on Elliptic Functions, A. Cayley. G. Bell & Sons, London, 1895.

Production of Steam From Electric Energy

In localities where hydroelectric power is abundant and steam loads are readily available, the production of steam from electric energy has proved to be a highly satisfactory means of utilizing surplus and off-peak power. This method of producing steam is particularly advantageous where cleanliness is important and in small establishments having intermittent demand for steam. Although the production of steam by this method has had a wider application in Canada, where the total installed capacity of such equipment exceeds 1,500,000 kw, numerous installations, totalling about 200,000 kw, also have been made in the United States. The design and operation of the principal types of equipment used for this purpose are discussed in this paper.

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ELECTRIC production of steam has proved to be the most economical and generally satisfactory means for the utilization of surplus and off-peak power in parts of the world where hydroelectric power is abundant and steam loads are readily available. This is because of the low unit cost of electric steam generating plants, the ease of control, and the satisfactory characteristics of the load. It should be understood, however, that the installation of hydroelectric generating capacity to be utilized for the production of steam is economically justifiable only under extremely unusual conditions. It is apparent that electric energy generated from fuel cannot be used economically for steam production in substantial amount under any circumstances. Surplus hydroelectric power may be available because of development beyond current needs, an economic depression, or the failure of bulk power customers at times to take their allotments. If off-peak power be available for as much as an 8 hour period regularly, it may be utilized profitably for steam production.

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The earlier electric steam generators were of the immersion type, which consists of a pressure vessel in which are inserted electric heaters in such a manner that the heater element will be immersed in the water. This type is particularly useful in capacities up to 100 kw and, where power rates are favorable, is used in hospitals, dairies, cleaning establishments, etc., for the production of small and intermittent supplies of steam. The cost per unit of capacity of the immersion generator is relatively high; consequently, for large installations the electrode type generally is used.

In the electrode steam generator, as the name indicates, the electric current is introduced into the vessel by means of insulated electrodes and flows through the water from one electrode to another or to the shell of the vessel. Thus the water itself is the resistance element, inexpensive and durable. Various types of electrode generators have been developed. These might be classified roughly as the baffle, the 2-compartment, and the single-compartment generators. The baffle type contains ceramic blocks so arranged that the water passages for the flow of electric current between electrodes are restricted. The object is to secure a higher resistance between electrodes and provide a low current density at the electrodes. Too great a current density will cause overheating of the electrodes, oxidation of the metal, and release of hydrogen gas. A baffle type of steam generator is shown in figure 1. It may be noted that porcelain bushings are utilized to insulate the conductor rods passing through the top end of

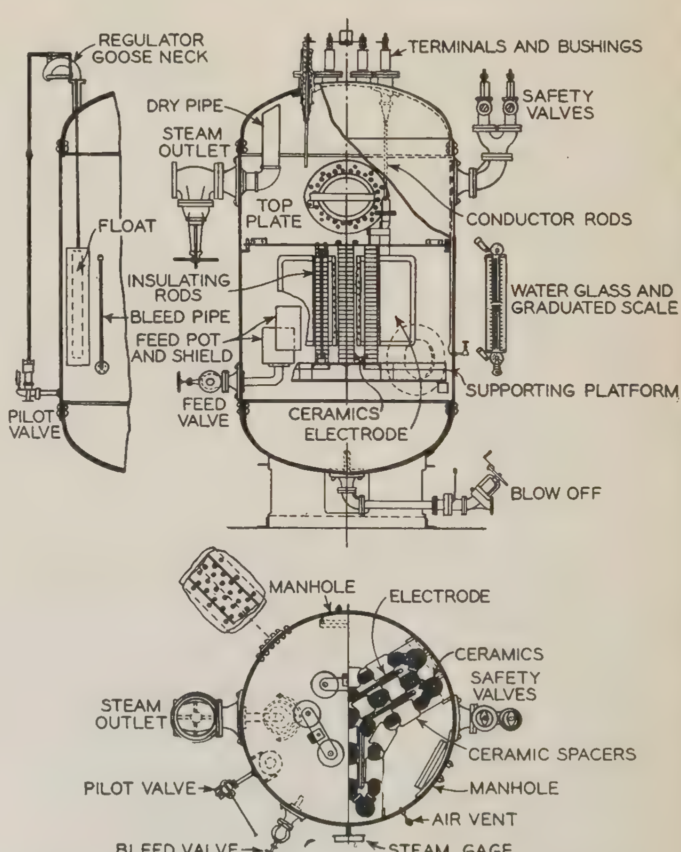


Fig. 1. Baffle type of electric steam generator

the pressure vessel; 2 of these in parallel are used on each of the 3 phases, the 2 conductor rods of each phase supporting a V-shaped electrode. The 3 electrodes are separated and surrounded by stacks of ceramic material which serve to limit and to direct the flow of electric current between the electrodes. The other features illustrated, with the exception of the bleed valve, are the same as are to be found on an ordinary fuel fired steam boiler.

A baffle type steam generator equipped with a water level regulator is shown in figure 2. It is necessary to control the water level in order to maintain the desired load. The device shown provides for manual adjustment of the water level, which, together with the proper variation in the amount of bleed water, will permit any desired load to be carried.

The 2-compartment type of generator contains an upper compartment within the shell of the pressure vessel, the shell itself forming the lower compartment. The electrodes are immersed in the water of the upper compartment. Water is conveyed from the lower to the upper compartment by means of a centrifugal pump. A return connection between the 2 compartments is provided with a regulating valve, by means of which the water level in the upper compartment, and the consequent depth of immersion of the electrodes, may be varied; this furnishes a ready means of varying the power input to the generator.

The 2-compartment type of generator is illustrated in figure 3. The electrodes, which are segmental in cross section, are suspended in the upper compartment by means of the conductor rods. Current flows between the electrodes and from the electrodes to the shell of the upper compartment, which is at ground potential. When greater current carrying capacity is desired, a grounded cylinder is installed inside the circle of the electrodes.

The single-compartment or Kaelin type of electric steam generator illustrated in figure 5 is constructed with the 3 electrodes of the 3 phase generator in a single compartment inside the pressure shell. It may be observed that each electrode is supported from a conductor rod passing through the top of the pressure vessel. The electrodes are circular in cross section, tapering downward to a hemispherical tip at the bottom, and are surrounded by a steel shell of

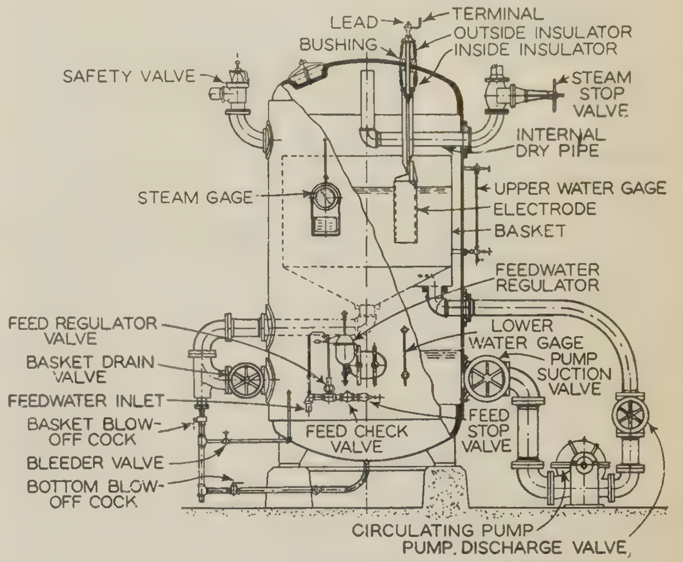
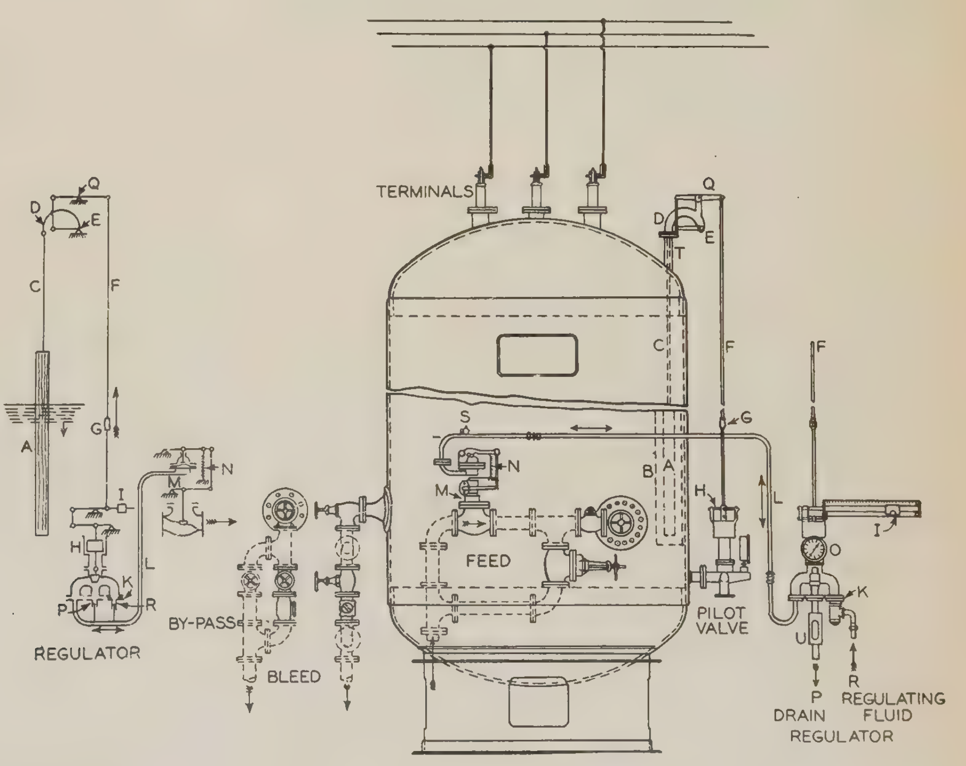


Fig. 3. Generator of the 2-compartment type with circulating pumps

Fig. 2. Baffle type generator equipped with water level regulator

For simplicity, the regulator is shown in schematic form at the left; letters on this diagram indicate the same points as corresponding letters on the main diagram



trefoil cross section; this arrangement is intended to distribute the current evenly over the surfaces of the electrodes. The feed water enters the vertical pipe at the bottom of the pressure vessel and flows upward, distributing the fresh water around the electrodes. The bleed connection is at the bottom of the pressure vessel in order to draw off the water containing the greatest concentration of salts.

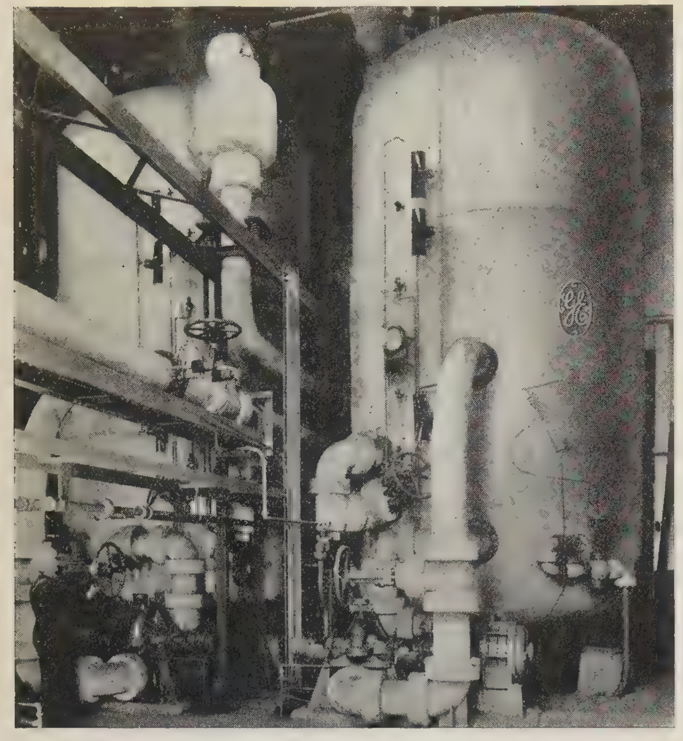


Fig. 4. Installation of 30,000-kw 3-phase 25-cycle 6,600-volt 2-compartment type generators. Maximum operating pressure, 200 pounds per square inch (gauge)

Kaelin steam generators of large capacity and high voltage have a separate shell for each phase. It may be noted in figure 6 that the electrode is supported by 3 conductor rods, which provide the necessary rigidity and current carrying capacity. The steel liner or false shell surrounding the electrode is circular in cross section. The feed water is introduced through an insulating tube close to the bottom of the electrode and flows upward, partly through an opening in the bottom of the electrode and out through openings in the side. The bleed is taken from the sump or mud drum at the bottom of the pressure vessel. The current flows from the electrode to the false shell through the water, then out through the pressure shell by way of uninsulated studs. The studs on the 3 phases are connected together by copper bars to form a neutral which is well grounded.

Operating Voltages

The electric steam generator may readily be designed to operate on any voltage up to 6,600 volts. For higher voltages it is necessary to have a feed water of high resistivity in order to secure reasonable operating efficiency. In general, capacities up to 1,000 kw can be designed most readily for 550 volt operation, up to 12,000 kw at 2,200 volts, and higher capacities at 6,600 volts. The higher the voltage the longer the required path through the water with a consequent increase in electrode areas and current capacity. It has been found that an average current density of one ampere per square inch is the maximum that can be used with carbon steel or cast iron electrodes without erosion and formation of hydrogen gas.

In several instances, the location of the steam generator has been near enough to the generating station so that power could be transmitted directly from the low voltage bus. The only major electrical apparatus required is a circuit breaker which may be in the generating station or at the load. Such an arrangement provides a grounded neutral on the bus. Sometimes the steam generator is supplied from the low voltage bus in the customer's substation, either in parallel with the primary load or from a spare transformer bank.

The usual arrangement for a large installation consists of a transformer bank connected to the high voltage line stepping down to 6,600 volts to supply one or more steam generators. The switching equipment may be either on the high voltage or low voltage side of the transformers.

Relaying and Control

The choice of the most suitable relay protection depends largely upon the specific conditions of each installation. For the isolated steam generator, usually the instantaneous excess current relay for short circuits and the instantaneous residual voltage relay, connected across the open corner delta secondary of a star/delta potential transformer set, will protect for all faults throughout the operating range of the generator.

For selective relaying of steam generators in parallel off the same low voltage bus, the instantaneous impedance relay, connected for phase current and phase-to-ground voltage, is used to assure selective protection between the units for ground faults. These same impedance relays usually are satisfactory also for short-circuit protection.

Power input to the steam generator may be controlled by varying the water level and consequently the immersion of the electrodes, which may be done by adjusting the feed water supply. This method has the disadvantage that the initial effect is negative; that is, when the feed water is reduced, the steam output is increased until the water level is lowered considerably, and the contrary when the feed water rate is increased. In some installations a closed tank is provided in which water from the steam generator is stored when operating at reduced load. This water is returned to the generator whenever it is desired to pick up load. The 2-compartment generator, as previously noted, is designed to operate on water level control, and storage space is provided in the lower compartment.

An unstable element is introduced into the control, however, by the negative temperature-resistance characteristic of water. With increasing pressure the temperature of saturated steam will increase correspondingly. The temperature of the water will follow closely that of the steam, with resultant decrease in resistivity and increased power input.

Another method is known as the conductivity control. The conductivity of the water in the generator depends upon the concentration of salts therein. This concentration can be reduced readily by bleeding a small amount of water from the generator and replacing it with fresh water. The concentration, and hence the conductivity, can be increased

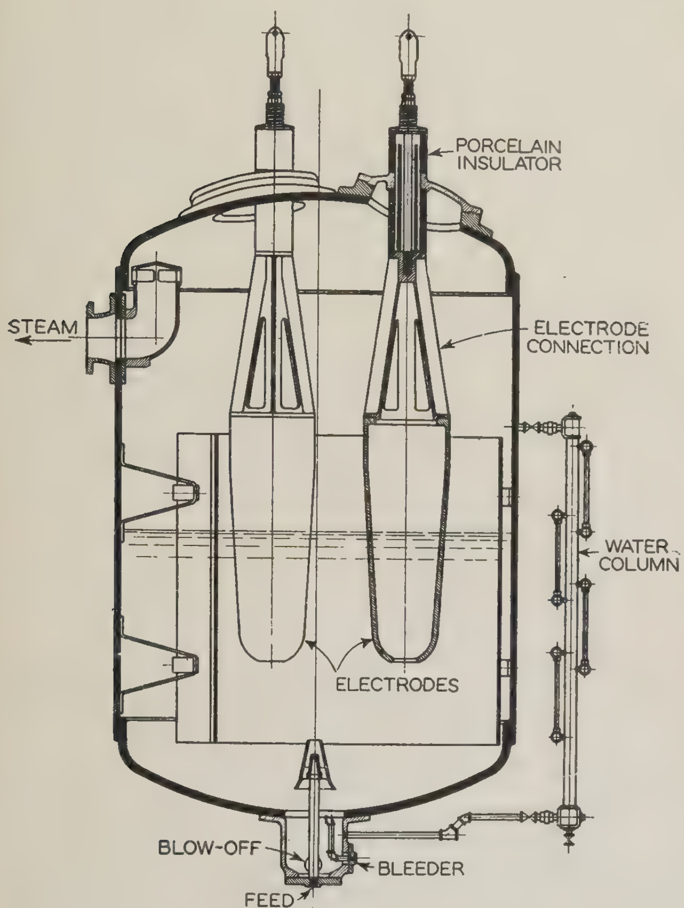


Fig. 5 (left). Single-compartment generator, 3 phases in one tank

by feeding a salt solution into the generator. To control rapid fluctuations in load in this way it is necessary to bleed heavily for a drop in steam demand, at the same time maintaining a practically constant water level by increasing the amount of feed. The cooling effect of this feed water counteracts the tendency to pick up load with increased pressure.

A special method of control not generally applicable is obtained by varying the voltage impressed on the terminals of the steam generator. In one instance the steam generator was operated on a separate bus in the power house and the attendant given control over the voltage. This method proved to be highly satisfactory.

The majority of electric steam generators at present in operation are controlled manually. Various forms of automatic control have been developed, however, the one most generally used being known as the Eaton control. This is a conductivity control with provision for automatically reducing the conductivity by bleeding and increasing the conductivity by feeding salt solution. Water level is maintained automatically, but is adjustable manually.

Feed Water

The principal loss of heat in the operation of an electric steam generator is that resulting from the bleed from the generator to maintain the proper conductivity. For a concentration of dissolved salts of not more than 60 parts per million or a resistivity of not less than 6,000 ohms per inch cube at 20 degrees centigrade, the generator will operate without excessive bleed. The formation of scale is not harmful except that, if allowed to accumulate in the bottom of the tank, it may clog the bleed outlet.

In some localities where organic matter is present in the feed water, the scale may adhere to the electrodes and interfere with the flow of the electric current. In some such instances, the electrodes are cleaned as often as once a month. The electric steam generator is subject to corrosion and pitting the same as fuel fired boilers. It has the disadvantage that

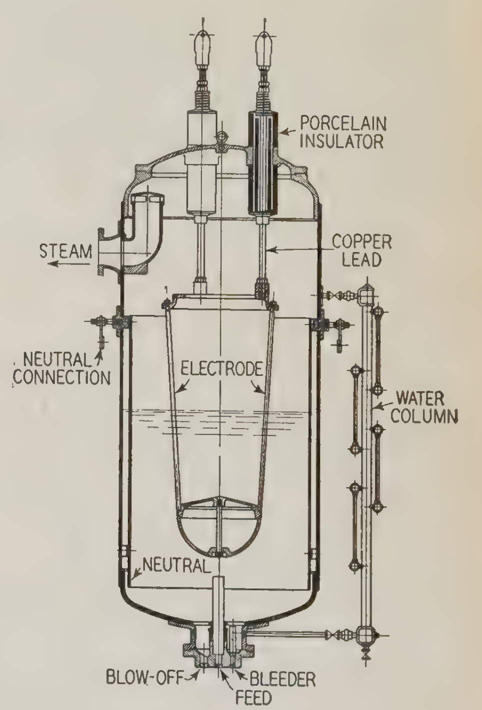


Fig. 6 (right). Single-compartment generator, one phase per tank

dissolved salts may not be used so freely in treating the water, and the advantage that the pressure shell may be protected by scale or other suitable coating.

Efficiency

Thermal losses of the electric steam generator are caused by radiation and by the bleed or discharge

of water from the generator to maintain the proper conductivity, as already explained. The radiation loss may be taken at 2 per cent. For a feed water of the characteristics mentioned, the bleed would be approximately 20 per cent of the feed. This would mean a reduction in efficiency of 4 per cent on account of the bleed or an operating efficiency of 94 per cent under these conditions. Several electric steam generators are operating at efficiencies varying from between 90 and 98 per cent.

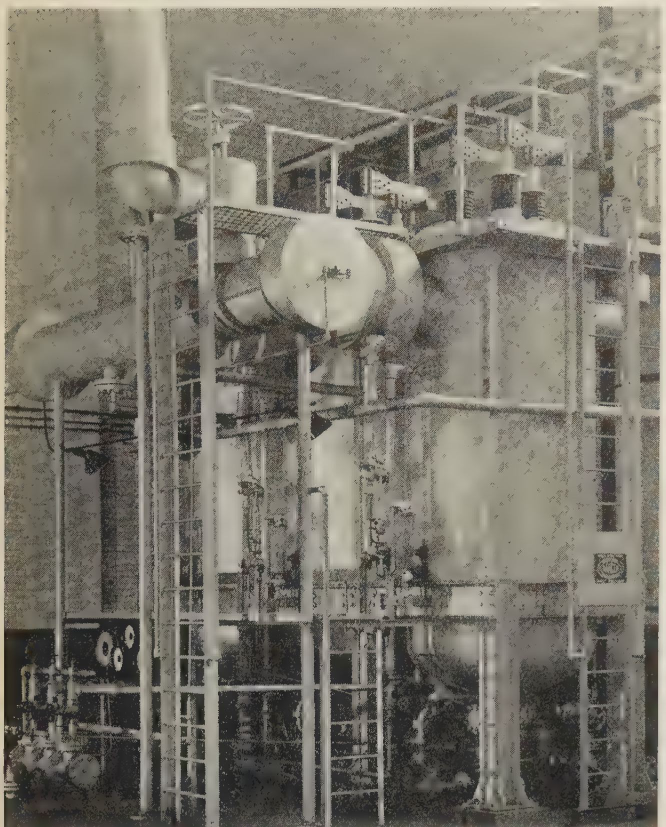


Fig. 7. Single-compartment 3-phase 3-tank, 6,600-volt 35,000-kw manually controlled generator

The efficiency is affected to a considerable extent by the design of the generator. For a given impressed voltage, electrode area, and spacing of electrodes, the water in the generator must have a conductivity suitable to carry the desired load. The higher this conductivity, the less the percentage of bleed and consequently the higher the efficiency.

The efficiency will be affected also to some extent by the character of the steam demand, particularly where conductivity control is used. A sudden drop in demand will require a heavy blowdown in order to prevent the safety valves from blowing. A sudden increase in demand will require the feeding of salt solution to maintain pressure. If this cycle be repeated frequently, it will result in a decrease in efficiency of from 2 to 5 per cent below that obtained under steady load conditions.

As already indicated, the efficiency is affected materially by the conductivity of the feed water. A resistivity of 6,000 ohms per inch cube at 20 degrees centigrade has been given as the lower limit for a good feed water. It is probable that most water supplies in the eastern United States have a resistivity of less than this figure. In such instances, no doubt it would be desirable to install heat interchangers or other means of recovering the waste heat in the bleed water.

If a high percentage of condensate can be returned to the steam generator, a raw water of relatively high conductivity may be used for the make-up. Where the electric steam generator is used in conjunction with fuel fired boilers, it may be possible to use 100 per cent condensate for the feed water of the steam generator. Under these conditions there would be no bleed from the steam generator except for load adjusting purposes.

Competitive Rate for Secondary Power

In order to replace fuel in the production of steam, the rate at which the electric energy is sold must be such that, in general, an effective heat unit will cost the same from the 2 sources. This relationship is expressed by the proportion

$$\frac{\text{Cost of electric energy}}{\text{Btu} \times \text{conversion efficiency}} = \frac{\text{Cost of fuel}}{\text{Btu} \times \text{furnace efficiency}}$$

Assuming coal at $5 per ton of 2,000 pounds

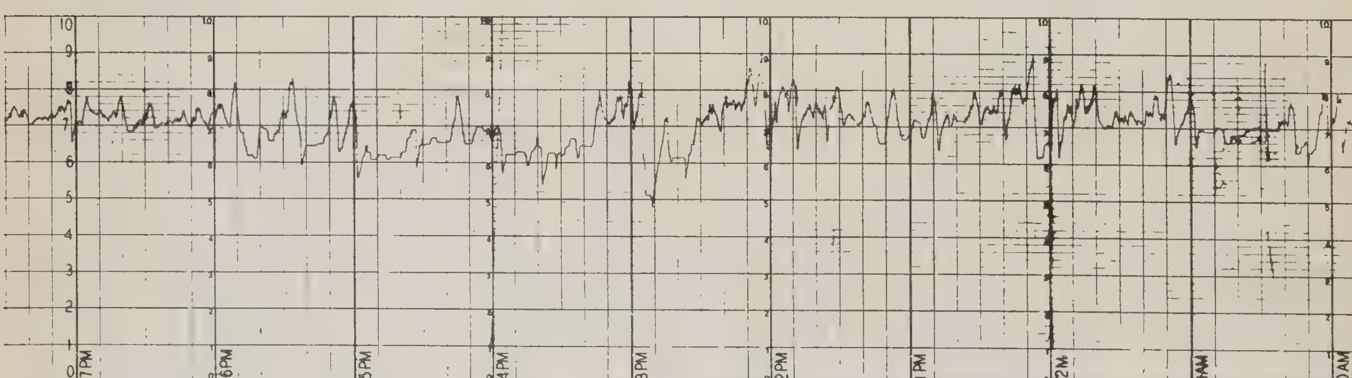


Fig. 8. Graph of load on 2 35,000 kw steam generators, one automatically controlled, in a newsprint mill. Full scale is 100,000 kw

on the grates, 13,600 effective Btu per pound, a furnace efficiency of 80 per cent, and a conversion efficiency in the electric steam generator of 95 per cent, the proportion would be

$$\frac{\text{Cost of a kilowatt-hour}}{3{,}415 \times 0.95} = \frac{\$5.00}{2{,}000 \times 13{,}600 \times 0.80}$$

or

Cost of a kilowatt-hour = \$0.000745 = 0.745 mill

At an annual load factor of 75 per cent, the annual earning of 1 kw of capacity would be \$4.90 In general, a kilowatt-year at 75 per cent load factor will be equal in value to a ton of coal.

Other considerations, aside from the cost of fuel, may affect the competitive price of electric energy. Some of these are: (1) saving on operating costs, (2) saving on maintenance, (3) cleanliness, and (4) convenience.

In a large steam plant a single operator is required for the electric steam generators. The control may be made automatic, if desired. The treatment of feed water for scale prevention ordinarily would not be necessary. The maintenance cost of steam genera-

Table I—Baffle Type Electric Steam Generators Installed in Canada

User	Location	No. Units	Size of Units, Kw	Total Kw
Interlake Tissue Mills	Merriton, Ont.	1	7,500	7,500
Provincial Paper Co.	Thorold, Ont.	1	7,500	7,500
Howard Smith Paper Co.	Cornwall, Ont.	1	20,000	20,000
Bathurst Paper Co.	Bathurst, N. B.	1	7,500	7,500
		4		42,500

Table II—Installations of 2-Compartment Type Electric Steam Generators in Canada

User	Location	No. Units	Size of Units, Kw	Total Kw
Pacific Mills Ltd.	Ocean Falls, B. C.	1	5,000	5,000
Corp. of Sherbrooke	Sherbrooke, Que.	1	750	750
City of Winnipeg	Winnipeg, Man.	2	7,500	15,000
Bennett's Ltd.	Chambly, Que.	1	600	600
Can. Gen. Elec. Co. Ltd.	Peterboro, Ont.	1	1,000	1,000
Quaker Oats Co.	Peterboro, Ont.	1	4,000	4,000
Gulf Pulp & Paper Co.	Clarke City, Que.	1	500	500
Donnacona Paper Co.	Donnacona, Que.	1	5,000	5,000
Cons. Mining & Smelting Co.	Trail, B. C.	3	1,500	4,500
Powell River Co.	Powell River, B. C.	1	5,000	5,000
Abitibi Pwr. & Paper Co.	Sturgeon Falls, Ont.	1	5,000	5,000
Abitibi Pwr. & Paper Co.	Iroquois Falls, Ont.	1	20,000	20,000
Can. Internat. Paper Co.	Temiskaming, Que.	2	8,000	16,000
Can. Cottons, Ltd.	Milltown, N. B.	1	1,500	1,500
Abitibi Pwr. & Paper Co.	Espanola, Ont.	1	5,000	5,000
Anglo Can. Pulp & Paper Co.	Limoilou, Que.	1	5,000	5,000
City of Winnipeg	Winnipeg, Man.	1	7,500	7,500
Spruce Falls Pulp & Paper Co.	Kapuskasing, Ont.	2	10,000	20,000
Toronto Hydro-Elec. System	Toronto, Ont.	1	1,000	1,000
Gatineau Pwr. Co.	Hawkesbury, Ont.	2	20,000	40,000
Spruce Falls Pwr. & Paper Co.	Kapukasing, Ont.	1	10,000	10,000
Thunder Bay Paper Co.	Fort William, Ont.	1	5,000	5,000
Abitibi Pwr. & Paper Co.	Sault Ste. Marie, Ont.	1	5,000	5,000
Powell River Co.	Powell River, B. C.	1	6,000	6,000
H. E. P. C.* for Ont. Paper Co.	Thorold, Ont.	3	30,000	90,000
Great Lakes Pwr. Co. Ltd.	Sault Ste. Marie, Ont.	1	5,000	5,000
H. E. P. C. for Provincial Paper Mills Ltd.	Port Arthur, Ont.	2	12,000	24,000
Pacific Mills Ltd.	Vancouver, B. C.	1	1,000	1,000
Winnipeg Electric Co. Ltd. for Can. Packers Ltd.	Winnipeg, Man.	1	6,000	6,000
Receiver for Minnesota and Ontario Paper Co. for Ft. Frances Pulp & Paper Co.	Fort Frances, Ont.	1	10,000	10,000
H. E. P. C. for Abitibi Pwr. & Paper Co. Ltd.	SmoothRockFalls, Ont.	2	25,000	50,000
		41		374,350

* Hydro-Electric Power Commission of Ontario.

Table III—Installations of Single-Compartment Type Electric Steam Generators in Canada

User	Location	No. Units	Size of Units, Kw	Total Kw
Abitibi Pwr. & Paper Co. Ltd.	Iroquois Falls, Ont.	2	20,000	40,000
	Beaupre, Que.	2	5,000	10,000
	Smooth Rock Falls, Ont.	2	2,000	4,000
	Fort Alexander, Man.	2	15,000	30,000
Aluminum Co. of Can., Ltd	Arvida, Que.	1	8,000	8,000
Anglo Can. Pulp & Paper Co.	Limoilou, Que.	1	35,000	35,000
Ayers, Ltd	Lachute, Que.	1	4,000	4,000
Beaver Wood Fibre Co.	Thorold, Ont.	1	3,000	3,000
Brown Corp. Ltd.	Latuque, Que.	1	35,000	35,000
Can. Car & Foundry Co. Ltd.	(Turcot) Montreal, Que.	1	5,000	5,000
Can. Cottons, Ltd	Cornwall, Ont.	1	2,000	2,000
Can. Electro Products, Ltd	Shawinigan Falls, Que.	1	5,000	5,000
Can. Industries, Ltd	Shawinigan Falls, Que.	2	10,000	20,000
Can. Internat. Paper Co.	Three Rivers, Que.	2	12,000	24,000
	Gatineau, Que.	3 1	42,000 21,000	147,000
N. B. Internat. Paper Co.	Dalhousie, N. B.	1	16,000	16,000
Internat. Pulp & Paper Co. of Nfld.	Corner Brook, Nfld.	1	20,000	20,000
Cascade Inn	Shawinigan Falls	1 1	300 500	800
Consolidated Paper Corp.	Grand Mere, Que.	2	25,000	50,000
	Shawinigan Falls, Que.	1 1	30,000 35,000	65,000
	Three Rivers	1 1	3,750 35,000	38,750
Dawson Elec. Lt. & Pwr. Co.	Dawson City, Yukon	1	500	500
Donnacona Paper Co. Ltd.	Donnacona, Que.	1 1	25,000 10,000	35,000
Goodyear Tire & Rubber Co.	New Toronto, Ont.	1	4,000	4,000
Lake St. John Pwr. & Paper Co.	Dolbeau, Que.	2	20,000	40,000
James McLaren & Co. Ltd.	Masson, Que.	1 4	300 16,000	64,300
Montreal Cottons, Ltd	Valleyfield, Que.	2	1,500	3,000
Montreal Lt. Ht. & Pwr. Cons.	Montreal, Que.	1 1	3,000 5,000	8,000
	Ville LaSalle, Que.	2	8,000	16,000
News Pulp & Paper Co.	Desbiens, Que.	1	1,800	1,800
Ontario Paper Co.	Thorold, Ont.	1	3,000	3,000
Port Alfred Pulp & Paper Co.	Port Alfred, Que.	1	35,000	35,000
Price Bros. & Co. Ltd.	Kenogami, Que.	1	7,000	7,000
	Kenogami, Que.	3	28,000	84,000
	Riverbend, Que.	2	32,000	64,000
Quebec Ry. Lt. Ht. & Pwr. Co.	Quebec, Que.	1 1	1,500 750	2,250
St.Lawrence Paper Mills Co.Ltd.,	Three Rivers, Que.	1 1	5,000 25,000	30,000
Shawinigan Chemicals, Ltd.	Shawinigan Falls, Que.	2	5,000	10,000
Howard Smith Paper Mills, Ltd.	Crabtree Mills, Que.	1	10,000	10,000
Spruce Falls Pulp & Paper Co. Ltd.	Kapuskasing, Ont.	1	1,500	1,500
Installations in Winnipeg	Winnipeg, Man.	28	100 and over	12,200
St. Justine Hospital	Montreal, Que.	1	1,500	1,500
Dominion Silk Dyeing & Finishing Co.	Drummondville, Que.	1	10,000	10,000
Northern B. C. Pwr. Co.	Prince Rupert, B. C.	1	500	500
Montreal Cottons, Ltd.	Valleyfield, Que.	1	1,700	1,700
Winnipeg Electric Co.	Winnipeg, Man.	1	2,000	2,000
J. R. Booth, Ltd. (paper mill)	Ottawa, Ont.	1	5,000	5,000
Dominion Rubber Co.	Montreal, Que.	1	8,000	8,000
Great Lakes Paper Co.	Fort William, Ont.	2	8,000	16,000
Winnipeg Heating Co.	Winnipeg, Man.	1	10,000	10,000
McGill University	Montreal, Que.	1	2,000	2,000
Boswell's Brewery	Quebec, Que.	1	2,500	2,500
J. J. Joubert Dairy	Montreal, Que.	1	2,000	2,000
Consolidated Paper Corp. (Belgo Mill)	Shawinigan Falls, Que.	1	35,000	35,000
Associated Textiles of Can.	Louiseville, Que.	1	10,000	10,000
Montreal Lt. Ht. & Pwr. Co.	Cedar Rapids, Que.	1	1,500	1,500
Other installations		6		13,100
		118		1,114,900

Table IV—Summary of Electric Steam Generator Installations in Canada

Type	Range in Kw. Capacity of Units	No.	Total Kw.
Baffle	7,500–20,000	4	42,500
Two Compartment	500–30,000	41	374,350
Single Compartment	300–42,000	118	1,114,900
Total		163	1,531,750

tors may be taken at $1 per million pounds of steam produced. The maintenance cost of one coal fired steam plant producing one billion pounds of steam per year is stated to be $38 per million pounds of steam produced.

It is difficult to evaluate the elimination of coal dust, smoke, and soot. In the manufacture of fine papers, textiles, etc., the improved cleanliness is of

Table V—Partial List of Electric Steam Generators Installed in the United States

User and Location	Capacity
Internat. Paper Co., Niagara Falls, N. Y.	5,000
Niagara Falls Pwr Co., Niagara Falls, N. Y.	19,000
Oxford Paper Co., Rumford, Maine	16,000
Aluminum Co. of America, Massena, N. Y.	7,000
Washington Pulp & Paper Co., Port Angeles, Wash.	5,000
Miller Falls Paper Co., Miller Falls, Mass.	350
Rochester Gas & Elec. Corp., Rochester, N. Y.	3,000
Ford Motor Co. (Green Island), Detroit, Mich.	3,200
Brown, Co., Berlin, N. H. (paper)	18,000
Washburn-Crosby Co. (flour)	3,000
Montana Pwr. Co., Missoula, Mont.	5,000
Washington Water Pw . Co., Spokane, Wash.	10,000
Mosiner Paper Mills Co., Mosiner, Wis.	2,500
St. Croix Paper Co., St. Croix, Me.	6,000
Union Bag & Paper Co., Hudson Falls, N. Y.	5,000
Hearts Delight Farm, Chazy, N. Y.	2,000
Red River Lumber Co., Westwood, Calif.	2,000
Keyes Fibre Co., Waterville, Me.	7,500

undoubted value in reducing costs and improving the quality of the product. In small establishments having intermittent demand for steam, such as dairies and laundries, the convenience of electric steam generation may outweigh all other considerations.

Cost of Installation

The cost of a large installation of electric steam generators with housing should not exceed $2 per kilowatt of capacity, including piping and electrical connections, switching equipment, and relaying. If transformers be required, the total cost ordinarily will not be more than $5 per kilowatt of installed capacity. These costs are based upon the assumption that no high voltage line construction will be required.

Operating Experience

Since 1921, more than 100 electric steam generators have been installed in Canada with a total rated capacity of 1,500,000 kw. Observations made on the operating results obtained on approximately 25 per cent of this total may be summarized as follows:

1. The electric steam generator is equal in operating reliability to electrical apparatus in general. Electrical breakdown is most likely to take place at the bushings that insulate the conductors passing through the pressure shell of the generator. Porcelain generally has been used for these bushings and has had a life of from 6 months to a year on the parts exposed to steam. A new type of ceramic material has been developed that has been found especially suitable for use in contact with steam. It is unglazed, free from thermal cracks, and promises to give long service.

2. Considered as a pressure vessel, the electric steam generator has given satisfactory service. The design is such that strains resulting from varying temperature are minimized. The pressure shell readily is protected from erosion caused by the passage of the current. Some pitting has been observed similar in character to that found in fuel fired boilers. Because of the comparatively small dimensions of the electric steam generator, it is feasible to design the pressure shell to have a high factor of safety and thus compensate for a considerable amount of pitting.

3. Because of its relatively small storage capacity, the electric steam generator is not as well adapted to carry a rapidly fluctuating load as the ordinary fuel fired boiler. It is advisable to provide an accumulator where the load is variable; however, several electric steam generator installations are handling such loads without the aid of an accumulator.

4. Maintenance on the electric steam generator is a matter of keeping joints steam tight, renewing gauge glasses, etc. Electrodes require renewing at intervals from 1 to 5 years.

5. Sufficient time has not elapsed since the general introduction of the electric steam generator to determine with any accuracy the rate at which depreciation takes place. However, it is reasonable to expect that an installation may be operated at least 10 years at full pressure rating.

In figure 8 is reproduced a section of a graphic wattmeter chart showing the total power input to 2 35,000 kw steam generators supplying a newsprint mill in which there are rapid fluctuations in the

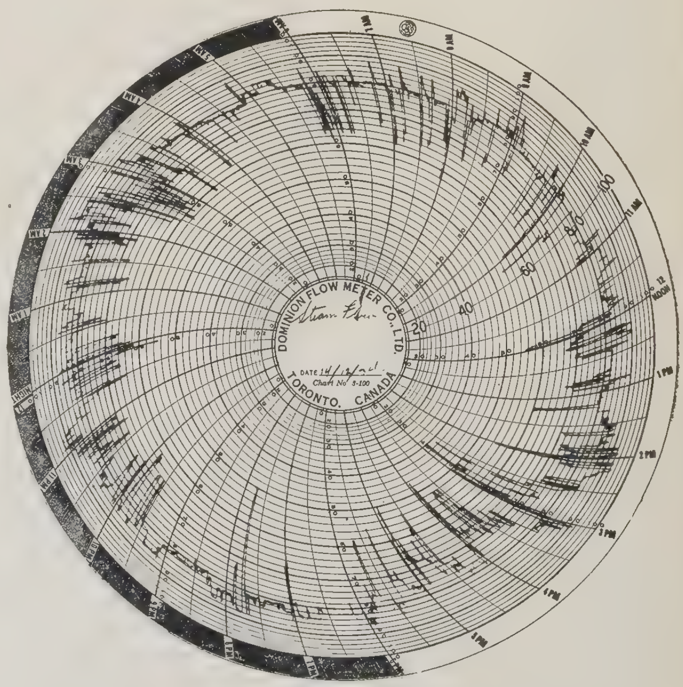


Fig. 9. Chart showing steam demand of newsprint mill of figure 8 for same day. Full scale equals 266,150 pounds of steam per hour at a pressure of 120 pounds per square inch, gauge

steam demand. One of the generators is controlled automatically and the other manually. The output for the day was 5,255,320 pounds of steam from and at 212 degrees Fahrenheit, and the input 1,675,200 kwhr; this corresponds to a conversion efficiency of 89.3 per cent. The chart reproduced in figure 9 shows the steam demand of the mill on the same day.

In tables I, II, and III are listed the electric steam generators of various types installed in Canada to date and table IV gives a summary of pertinent data on these installations. Complete information regarding installations in the United States was not available to the author; however, the best information available indicates that there are no installations of the baffle type, and that the total capacity of the 2-compartment and single-compartment types is in the neighborhood of 100,000 kw each. Table V gives a partial list of installations in the United States.

Transmission Line Catenary Calculations

A simple and accurate method is described for compiling stringing charts for overhead transmission lines, for either horizontal or inclined spans. All calculations can be carried out with a 20 inch slide rule, and no tables of functions are required other than those included in this paper. The procedure is the same for horizontal and for oblique spans. Moreover, no loss of accuracy is suffered as the inclination of the span is increased. The final result is obtained by means of a graphical solution which, in principle, is based upon the Thomas chart.

By
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THE method for carrying out sag and tension calculations for overhead transmission lines described in this paper was developed when the U. S. Bureau of Reclamation was confronted with the problem of designing a number of steep spans between the transformers on the roof of the Boulder Canyon power plant and the switch yard on the rim of the canyon. In this case it was found that the procedures commonly used in sag and tension calculations lacked either simplicity or accuracy, or both.

In the proposed method, the length, sag, and tension are calculated in terms of an arbitrary parameter z. All formulas are first rigorously derived from catenary relations, and then simplified by neglecting small quantities. The accuracy of the calculations is made consistent with good designing practice, on the one hand, and with the limitations of field measurements on the other.

Although originally intended only for steep spans, the method is applicable to spans of any inclination whatever. The only limitation is that the parameter z should be less than 0.5 if accuracy and simplicity are to be maintained. However, in practical problems of transmission line design z is always well within this limiting value.

In order to use the method intelligently, it is not necessary to follow all derivations in this paper. It will be sufficient to read from "Graphical Solution" to "Example 2," inclusive.

A paper recommended for publication by the A.I.E.E. committee on power transmission and distribution. Manuscript submitted June 4, 1934; released for publication Sept. 5, 1934.

The investigation described in this paper was carried out under the supervision of R. E. Glover, engineer. All design work and design studies for the Bureau are under the direction of J. L. Savage, chief designing engineer. All engineering and construction work is under the direction of R. F. Walter, chief engineer, Denver, Colo. All activities of the Bureau are under the general charge of Dr. Elwood Mead, commissioner, Washington, D. C.

Notation and Units

T	= tension at any point in cable	pounds
H	= horizontal component of tension	pounds
T_1	= tension at upper support	pounds
T_2	= tension at lower support	pounds
T_e	= effective (or average) tension of cable	pounds
w	= weight of cable per unit length	pounds per foot
h	= wind load per unit length of cable	pounds per foot
v	= ice load per unit length of cable	pounds per foot
w'	= $\sqrt{(w+v)^2 + h^2}$, resultant force per unit length	pounds per foot
ϕ	= angle between w and w'	
S	= actual length of cable	feet
S_0	= unstressed length of cable	feet
c	= straight-line distance between supports	feet
d	= sag of cable	feet
D	= deflection of cable	feet
x, y	= co-ordinates of any point on cable	feet
x_1, y_1	= co-ordinates of upper support	feet
x_2, y_2	= co-ordinates of lower support	feet
x', y'	= co-ordinates of any point on line of supports	feet
a	= horizontal spacing of supports	feet
b	= vertical spacing of supports	feet
a'	= spacing of supports in plane of w', at right angles to vector w'	feet
b'	= spacing of supports in plane of w', in the direction of vector w'	feet
A	= area of cross-section of cable $\Big\}$ AE	pounds
E	= modulus of elasticity of cable	

θ	= temperature of cable	degrees fahrenheit
α	= coefficient of linear expansion of cable	feet per foot per degree fahrenheit
z	$= aw/2H$, a parameter	pure number
$F(z)$	$= \left(\frac{\sinh z}{z}\right)^2 - 1$	pure number
(z)	$= \frac{1}{6}\left(z^2 + \frac{z^4}{20}\right)$	pure number

Length, Tension, and Sag

The length, tension, and sag will be written as functions of the parameter z. It will be assumed for the time being that there is no wind load or ice load.

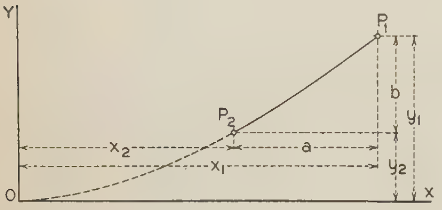

Fig. 1. Representation of the cable arc

Standard Formulas. Let the cable be represented by the arc P_1P_2 of any catenary drawn through the points P_1 and P_2. The horizontal and vertical spacings are a and b, respectively (see figure 1). The equation of the catenary, referred to the point O where it has a horizontal tangent, is

$$y = \frac{H}{w}\left(\cosh\frac{x}{H/w} - 1\right) \tag{1}$$

The length of arc from (0, 0) to (x, y) is given by

$$s = \frac{H}{w}\sinh\frac{x}{H/w} \tag{2}$$

The tension at the point (x, y) is

$$T = H\cosh\frac{x}{H/w} \tag{3}$$

Locating the End Points. Before one can actually make use of equations 1, 2, and 3, the end points x_1, y_1 and x_2, y_2 must be located with respect to the co-ordinate axes (see figure 1).

From equation 1

$$\frac{y_1}{H/w} - \frac{y_2}{H/w} = \cosh\frac{x_1}{H/w} - \cosh\frac{x_2}{H/w}$$

By transforming and making the substitutions

$$x_1 - x_2 = a,\ y_1 - y_2 = b \tag{4}$$

one obtains:

$$\frac{b}{H/w} = 2\sinh\frac{aw}{2H}\sinh\frac{2x_1 - a}{2H/w}$$

Upon solving this for x_1 and putting

$$z = \frac{aw}{2H}, \tag{5}$$

one has

$$\frac{x_1}{H/w} = \operatorname{arc\,sinh}\frac{bz}{a\sinh z} + z, \tag{6}$$

and

$$\frac{x_2}{H/w} = \frac{x_1 - a}{H/w} = \operatorname{arc\,sinh}\frac{bz}{a\sinh z} - z \tag{7}$$

Length of Cable. By virtue of equation 2 one has at once (see figure 1):

$$S = \text{arc } P_1P_2 = \text{arc } OP_1 - \text{arc } OP_2 = \frac{H}{w}\left(\sinh\frac{x_1}{H/w} - \sinh\frac{x_2}{H/w}\right)$$

Transform and make use of the first equation 4. Then:

$$S = \frac{2H}{w}\sinh\frac{aw}{2H}\cosh\frac{x_1 + x_2}{2H/w}$$

Use equations 5, 6, and 7, and then simplify. This gives:

$$S = \sqrt{a^2\left(\frac{\sinh z}{z}\right)^2 + b^2} \tag{8}$$

By putting

$$F(z) = \left(\frac{\sinh z}{z}\right)^2 - 1$$

one has:

$$S = \sqrt{a^2(1 + F) + b^2} = \sqrt{c^2 + a^2F}$$

where c is the straight-line distance between supports.

Expand $F(z)$ into a power series:

$$F(z) = \frac{2^3}{4!}z^2 + \frac{2^5}{6!}z^4 + \frac{2^7}{8!}z^6 + \ldots$$

and:

$$S^2 = c^2 + a^2F(z) = c^2 + \frac{2^3}{4!}a^2z^2 + \frac{2^5}{6!}a^2z^4 + \frac{2^7}{8!}a^2z^6 + \ldots \tag{9}$$

Assume that

$$\sqrt{c^2 + a^2F} = c + m_2z^2 + m_4z^4 + m_6z^6 + \ldots \tag{10}$$

By squaring both sides of equation 10 and comparing with equation 9, one evaluates the coefficients m. Remembering that $c^2 = a^2 + b^2$, one finally obtains:

$$S = \sqrt{c^2 + a^2F} = c + \frac{a^2}{6c}z^2 + \frac{a^2}{6c}\left[\frac{1}{20} + \frac{(b/c)^2}{12}\right]z^4 + \ldots$$

Since this series converges at least as rapidly as the right-hand side of equation 9, one can neglect

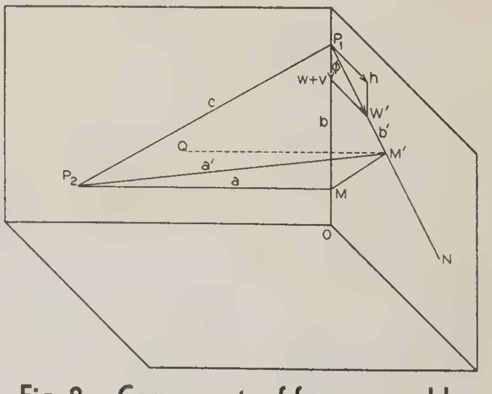

Fig. 2. Components of forces on cable

$b = MP_1$ $b' = M'P_1$ ϕ = the angle MP_1M'
Draw P_2M' perpendicular to P_1N
Draw $M'Q$ parallel to MP_2
P_1M' is perpendicular to P_2M' by construction
P_1M' is perpendicular to $M'Q$, since $M'Q$ is parallel to MP_2
Therefore P_1M' is perpendicular to the plane of $MM'P_2$
Therefore P_1M' is perpendicular to MM'
Therefore the angle $MM'P_1$ = 90 degrees
Therefore $b' = b\cos\phi$

all terms beginning with the fourth. One then has, upon rearranging:

$$S - c = \frac{a^2}{6c}\left(z^2 + \frac{z^4}{20}\right) + \frac{a^2b^2}{72c^3}z^4 \tag{11}$$

The quantity $S - c$ is the slack of the cable, or the length of the cable in excess of the span length c.

By putting

$$f(z) = \frac{1}{6}\left(z^2 + \frac{z^4}{20}\right), \tag{12}$$

one has:

$$S - c = \frac{a^2}{c}\,f(z) + \frac{a^2b^2}{72c^3}z^4 \tag{13}$$

Values of $f(z)$ and z^4 are given in table I. In most cases it will be found that the term involving z^4 can be neglected.

Upper-Support Tension. By virtue of equation 3,

$$T_1 = H\cosh\frac{x_1}{H/w}$$

By making use of equation 6, and then simplifying, one has:

$$T_1 = \frac{w}{2}\left\{\sqrt{a^2\left(\frac{\sinh z}{z}\right)^2 + b^2}\,\coth z + b\right\}$$

or, by equation 8,

$$T_1 = \frac{w}{2}\,(S\coth z + b) = {}^1/_2(wS)\coth z + {}^1/_2wb \tag{14}$$

Lower-Support Tension. Proceeding as above, one finds:

$$T_2 = \frac{w}{2}\,(S\coth z - b) = {}^1/_2(wS)\coth z - {}^1/_2wb \tag{15}$$

Values of coth z are given in table I.

Note that the product wS is a constant, equal to the total weight of the cable.

Effective Tension. Divide the unstressed length of the cable into elements ΔS_0. When the cable is suspended the length of each element becomes

$$\Delta S = \Delta S_0\left(1 + \frac{T}{AE}\right) \tag{16}$$

where A is the area of cross section and E is the modulus of elasticity. Then:

$$S = \int_0^{S_0} dS_0 + \frac{1}{AE}\int_0^{S_0} T dS_0 = S_0 + \frac{1}{AE}\int_0^{S_0} T dS_0 \tag{17}$$

By transforming, one obtains

$$\frac{\frac{1}{S_0}\int_0^{S_0} T dS_0}{S - S_0} = \frac{AE}{S_0} \tag{18}$$

The effective tension T_e is defined as that value of the tension T which satisfies Hooke's law in its simple form: $\frac{T}{S - S_0} = \frac{AE}{S_0}$

It follows at once from equation 18 that the effective tension of the cable is

$T_e = \frac{1}{S_0}\int_0^{S_0} T dS_0$ or, very nearly

$$T_e = \frac{1}{S}\int_0^{S} T dS \tag{19}$$

Table I—Functions of z

z	f(z)	coth z	1/z	z^4	z^3
0.010	0.00001667	100.003	100.000	0.00000001	0.0000010
0.020	0.0000666	50.007	50.000	0.00000016	0.0000080
0.030	0.0001500	33.343	33.3333	0.00000081	0.0000270
0.040	0.0002667	25.013	25.0000	0.00000256	0.0000640
0.050	0.0004167	20.017	20.0000	0.00000625	0.0001250
0.060	0.0006001	16.687	16.6667	0.00001296	0.0002160
0.070	0.0008169	14.309	14.2857	0.00002401	0.0003430
0.080	0.001067	12.527	12.5000	0.00004096	0.0005120
0.090	0.001351	11.141	11.1111	0.00006561	0.0007290
0.100	0.001668	10.0333	10.0000	0.0001000	0.001000
0.110	0.002018	9.1275	9.0909	0.0001464	0.001331
0.120	0.002402	8.3733	8.3333	0.0002074	0.001728
0.130	0.002819	7.7356	7.6923	0.0002856	0.002197
0.140	0.003270	7.1895	7.1429	0.0003842	0.002744
0.150	0.003754	6.7166	6.6667	0.0005063	0.003375
0.160	0.004272	6.3032	6.2500	0.0006554	0.004096
0.170	0.004824	5.9389	5.8824	0.0008352	0.004913
0.180	0.005409	5.6154	5.5556	0.001050	0.005832
0.190	0.006028	5.3263	5.2632	0.001303	0.006859
0.200	0.006680	5.0665	5.0000	0.001600	0.008000
0.205	0.007019	4.9462	4.87805	0.001766	0.008615
0.210	0.007366	4.8317	4.76190	0.001945	0.009261
0.215	0.007722	4.7226	4.65116	0.002137	0.009938
0.220	0.008086	4.6186	4.54545	0.002343	0.010648
0.225	0.008459	4.5192	4.44444	0.002563	0.01139
0.230	0.008840	4.4242	4.34783	0.002798	0.01217
0.235	0.009230	4.3334	4.25532	0.003050	0.01298
0.240	0.009628	4.2464	4.16667	0.003318	0.01382
0.245	0.010034	4.1630	4.08163	0.003603	0.01471
0.250	0.010449	4.0830	4.00000	0.003906	0.01563
0.255	0.010873	4.0062	3.92157	0.004228	0.01658
0.260	0.011305	3.9324	3.84615	0.004570	0.01758
0.265	0.011745	3.8615	3.77358	0.004932	0.01861
0.270	0.012194	3.7933	3.70370	0.005314	0.01968
0.275	0.012652	3.7276	3.63636	0.005719	0.02080
0.280	0.013118	3.6643	3.57143	0.006147	0.02195
0.285	0.013592	3.6033	3.50877	0.006598	0.02315
0.290	0.014076	3.5444	3.44828	0.007073	0.02439
0.295	0.014567	3.4876	3.38983	0.007573	0.02567
0.300	0.015068	3.4327	3.33333	0.008100	0.02700
0.305	0.015576	3.3797	3.27869	0.008654	0.02837
0.310	0.016094	3.3285	3.22581	0.009235	0.02979
0.315	0.016620	3.2789	3.17460	0.009846	0.03126
0.320	0.017154	3.2309	3.12500	0.01049	0.03277
0.325	0.017697	3.1845	3.07692	0.01116	0.03433
0.330	0.018249	3.1395	3.03030	0.01186	0.03594
0.335	0.018809	3.0959	2.98507	0.01259	0.03760
0.340	0.019378	3.0536	2.94118	0.01336	0.03930
0.345	0.019956	3.0126	2.89855	0.01417	0.04106
0.350	0.020542	2.9729	2.85714	0.01501	0.04288
0.355	0.021137	2.9343	2.81690	0.01588	0.04374
0.360	0.021740	2.8968	2.77778	0.01680	0.04666
0.365	0.022352	2.8603	2.73973	0.01775	0.04863
0.370	0.022973	2.8249	2.70270	0.01874	0.05065
0.375	0.023602	2.7905	2.66667	0.01978	0.05273
0.380	0.024240	2.7570	2.63158	0.02085	0.05487
0.385	0.024887	2.7245	2.59740	0.02197	0.05707
0.390	0.025543	2.6928	2.56410	0.02313	0.05932
0.395	0.026207	2.6620	2.53165	0.02434	0.06163
0.400	0.026880	2.6319	2.50000	0.02560	0.06400
0.405	0.027562	2.6027	2.46914	0.02690	0.06643
0.410	0.028252	2.5742	2.43902	0.02826	0.06892
0.415	0.028951	2.5464	2.40964	0.02966	0.07147
0.420	0.029659	2.5193	2.38095	0.03112	0.07409
0.425	0.030376	2.4929	2.35294	0.03263	0.07677
0.430	0.031102	2.4672	2.32558	0.03419	0.07951
0.435	0.031856	2.4421	2.29885	0.03581	0.08232
0.440	0.032579	2.4175	2.27273	0.03748	0.08518
0.445	0.033331	2.3936	2.24719	0.03921	0.08812
0.450	0.034092	2.3702	2.22222	0.04101	0.09113
0.455	0.034861	2.3474	2.19780	0.04286	0.09420
0.460	0.035640	2.3251	2.17391	0.04477	0.09734
0.465	0.036427	2.3033	2.15054	0.04675	0.1005
0.470	0.037223	2.2821	2.12766	0.04880	0.1038
0.475	0.038028	2.2613	2.10526	0.05091	0.1072
0.480	0.038842	2.2409	2.08333	0.05308	0.1106
0.485	0.039665	2.2210	2.06186	0.05533	0.1141
0.490	0.040497	2.2016	2.04082	0.05765	0.1176
0.495	0.041338	2.1826	2.02020	0.06004	0.1213
0.500	0.042188	2.1640	2.00000	0.06250	0.1250

By making use of equations 2 and 3, one obtains:

$$T_e = \frac{H}{S}\int_{x_2}^{x_1} \cosh^2\frac{x}{H/w}\,dx \tag{20}$$

Now, integrate equation 20:

$$T_e = \frac{H^2}{2wS}\left\{\sinh\frac{x_1}{H/w}\cosh\frac{x_1}{H/w} - \sinh\frac{x_2}{H/w}\cosh\frac{x_2}{H/w} + \frac{x_1 - x_2}{H/w}\right\}$$

Substitute from equations 5, 6, and 7, and simplify:

$$T_e = \frac{wS}{4z}\left\{\frac{S^2+b^2}{S^2}\, z \coth z + \frac{a^2}{S^2}\right\} \tag{21}$$

Expand $z \coth z$ into a power series:

$$z \coth z = 1 + \frac{1}{3}z^2 - \frac{1}{45}z^4 + \ldots \tag{22}$$

Since z is always less than one-half, all terms beginning with the third can be neglected. Substituting the first 2 terms into equation 21, one has:

$$T_e = \frac{wS}{4z}\left\{1 + \frac{c^2}{S^2} + \frac{1}{3}z^2 + \frac{b^2}{3S^2}z^2\right\}$$

From equation 9, by long division, one obtains

$$\frac{c^2}{s^2} = 1 - \frac{1}{3}\frac{a^2}{c^2}z^2 + \ldots = 1 + \frac{1}{3}\left(\frac{b^2}{c^2} - 1\right)z^2 + \ldots$$

Substitute this for the second term in braces, but replace S^2 by c^2 in the last term in braces (which is small). Then:

$$T_e = {}^1/_2(wS)\cdot\frac{1}{z} + \frac{(wS)b^2}{6c^2}\cdot z \tag{23}$$

Values of $1/z$ are given in table I. In most cases it will be found that the term involving z can be neglected.

As mentioned before, the product wS is equal to the total weight of the cable, and therefore remains constant (for a given load). To establish the value of wS, one must know the values of w and S at the same temperature and same tension. Since w is generally measured in the laboratory, at zero tension and room temperature, one should, in calculating the weight of the cable, use the zero-tension room-temperature value of S, that is, the unstressed length S_0 at 60 to 70 degrees fahrenheit.

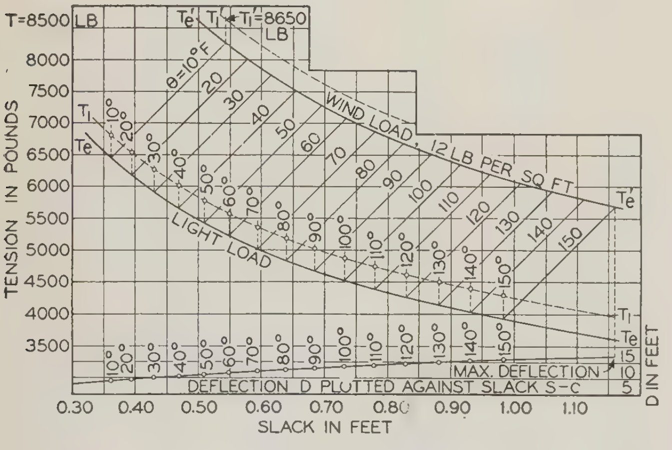

Fig. 3. Tension-temperature chart

512,000 circular mil, 1.4 inch diameter, type HH hollow copper conductor
Horizontal spacing = 475 feet
Vertical spacing = 435 feet
Maximum tension = 8,650 pounds
Minimum temperature = 10 degrees fahrenheit
Maximum load = 12 pounds per square foot—wind load

EXPLANATION

T'_1 = Upper support tension, 12 pounds per square foot wind load
T'_e = Effective tension, 12 pounds per square foot wind load
T_1 = Upper support tension, light
T_e = Effective tension, light

In the "Summary of Formulas," which follows, wS has been replaced by wS_0, where w denotes the weight per foot of the cable at zero tension and room temperature.

Deflection and Sag. Deflection is defined as the maximum deviation of the cable from the line of supports, measured at right angles to the line of supports.

Sag is defined as the maximum deviation of the cable from the line of supports, measured in the direction of the resultant force acting on the cable. (In case there is no wind, the sag is vertical.) A mathematical relation between the deflection D and the sag d is given in equation 28.

The equation of the line of supports is

$$y' = y_1 + \frac{b}{a}(x - x_1) \tag{24}$$

From equations 6 and 5, one obtains

$$x_1 = \frac{a}{2z}\,\text{arc sinh}\,\frac{bz}{a \sinh z} + \frac{a}{2} \tag{25}$$

By equations 1 and 3,

$$y = \frac{T}{w} - \frac{H}{w} \tag{26}$$

and, therefore, one has

$$y_1 = \frac{T_1}{w} - \frac{H}{w} = \frac{T_1}{w} - \frac{a}{2z} \tag{27}$$

The deflection is given by

$$D = \max.\left[\frac{a}{c}(y' - y)\right] = \frac{a}{c}\left\{\max.\,[y' - y]\right\} = \frac{a}{c}\cdot d \tag{28}$$

where y and y' are defined by equations 1 and 24, respectively, and d is the sag. The difference $y' - y$ is maximum when

$$x = \frac{a}{2z}\,\text{arc sinh}\,\frac{b}{a} \tag{29}$$

Substitute equations 25, 27, and 29 into equations 1 and 24, subtract equation 1 from 24 and simplify:

$$\max.\,[y' - y] = \frac{1}{2z}\left[Sz\coth z - c + b\,\text{arc sinh}\,\frac{bz(S-c)}{a^2 \sinh z}\right] \tag{30}$$

Now simplify equation 30 in the following manner:

Substitute for S from equation 11, for $z \coth z$ from equation 22, and for the ratio $z/\sinh z$ as follows:

$$\frac{z}{\sinh z} = 1 - {}^1/_6\, z^2 + \ldots.$$

The sinh being small, replace the arc sinh by the sinh.
Drop all terms containing powers of z higher than the third.

One then has:

$$d = \max.\,[y' - y] = \frac{c}{4}\cdot z + \frac{3a^2 - 2b^2}{144c}\cdot z^3 \tag{31}$$

and:

$$D = \frac{a}{c}\cdot d = \frac{a}{4}\cdot z + \frac{3a^2 - 2b^2}{144c^2}\,a\cdot z^3 \tag{32}$$

Values of z^3 are given in table I.

For short spans the second term in equations 31 and 32 may be dropped (see "Example 1," which follows). Then:

$$\text{Sag} = d = {}^1/_4\, c \cdot z, \qquad \text{Deflection} = D = {}^1/_4\, a \cdot z$$

For long spans with a relatively small difference in elevation between supports, b^2 is negligible compared to a^2 (see "Example 2," which follows) and therefore:

$$d = {}^1/_4\, c \cdot z + {}^3/_{144}\, c \cdot z^3, \qquad D = {}^1/_4\, a \cdot z + {}^3/_{144}\, a \cdot z^3 \tag{33}$$

Correction for Wind Load and Ice Load

If the cable is covered with ice, the force of gravity per unit length of the cable is $w + v$, where w is the weight of the conductor (in pounds per foot) and v is the weight of ice (in pounds per foot of cable).

If the cable is acted upon by a horizontal wind exerting a force h per unit length of the cable (at right angles to the no-wind plane of the cable), the cable will hang in an oblique plane determined by the line of supports and the direction of the resultant w' of the gravity force $w + v$ and the wind force h.

The formulas developed above are still applicable in case of the wind load and ice load, provided one replaces:

w by w', where $w' = \sqrt{(w + v)^2 + h^2}$

a and b by a' and b', respectively, where:

b' is the spacing between supports in the oblique plane, measured in the direction of the force w';

a' is the spacing between supports in the oblique plane, measured at right angles to the direction of w'.

It is easily seen from figure 2 that:

$$b' = b \cos \phi = b\, \frac{w + v}{w'} \tag{34}$$

$$a' = \sqrt{c^2 - b'^2} \tag{35}$$

Graphical Solution

By assigning arbitrary values to the parameter z, mutually corresponding values of $S - c$, T_e, and D can be calculated. The effective tension T_e can then be plotted against the slack $S - c$. Such a length-tension chart is shown in figure 3. However, before one can make use of the chart, the elastic properties of the cable must be taken into consideration.

Hooke's Law. When the temperature is constant, the effective tension and the length of the cable are related by Hooke's law. In differential notation, one has

$$\frac{\partial T_e}{\partial S} = \frac{AE}{S_0} \qquad (\theta = \text{constant}) \tag{36}$$

The unstressed length S_0 is, strictly speaking, a function of temperature. However, since the quantity AE is only approximately constant, the temperature variation of S_0 may be neglected entirely. The symbol S_0 may be taken to denote unstressed length at room temperature.

Change of Load. Assume that one is given a point $(S - c,\ T_e')$ on the wind load curve in figure 3, and that subsequently the wind load is removed. Here one has a change at constant temperature, and therefore equation 36 applies. Draw a straight line through $(S - c,\ T_e')$ with slope AE/S_0. The intersection of this line with the light load curve locates the new point.

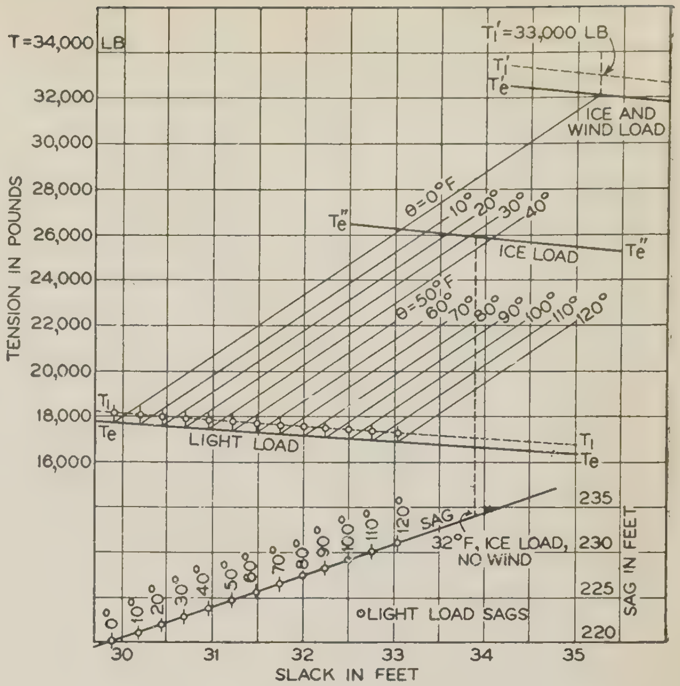

Fig. 4. Tension-temperature chart

Stranded aluminum conductor with steel core
Horizontal spacing = 4,279 feet
Vertical spacing = 185.5 feet
Maximum tension = 33,000 pounds
Minimum temperature = zero degrees fahrenheit
Maximum load = 12 pounds per square foot wind and $^1/_2$ inch ice

EXPLANATION
T_1 = Upper support tension
T_e = Effective tension
Unprimed = light load
Primed = 12 pounds per square foot wind and $^1/_2$ inch ice load
Double primed = $^1/_2$ inch ice load

Change of Temperature. Now, assume that one is given a point $(S - c,\ T_e)$ on the light load curve in figure 3 and that the temperature rises by $\Delta\theta$ degrees fahrenheit. Since the length S, tension T_e, and temperature θ all vary simultaneously, one can write:

$$dS = \frac{\partial S}{\partial \theta}\, d\theta + \frac{\partial S}{\partial T_e}\, dT_e \tag{37}$$

Obviously, one may analyze dS into 2 components which can be accounted for one at a time. First, let S vary with θ only. Then, one is following a constant-tension path, that is, a horizontal line. This shifts the point to the position

$$[(S + S\alpha\Delta\theta) - c,\ T_e],$$

where α is the thermal coefficient of expansion. Now, let θ remain constant and let S vary with T_e only. This time one is following a constant-temperature line, to its intersection with the light load curve (since the point *must* be on the light load curve).

Construction of Chart. In practice, a number of constant-temperature lines are drawn, as in figure 3 or figure 4. Changes in length and tension due to varying temperature are found by following the

proper constant-load curve to the intersection with the proper constant-temperature line. The chart must be so arranged that the minimum temperature corresponds to the maximum permissible tension at maximum load.

Summary of Formulas

Basic Formulas. Slack (length of cable minus span length):

$$s - c = \frac{a^2}{c} f(z) + \frac{a^2 b^2}{72c^3} z^4 \tag{A}$$

Tension at upper support:

$$T_1 = (^1/_2 wS_0) \coth z + {}^1/_2 wb \tag{B}$$

Tension at lower support:

$$T_2 = (^1/_2 wS_0) \coth z - {}^1/_2 wb \tag{C}$$

Effective or average tension:

$$T_e = (^1/_2 wS_0) \cdot \frac{1}{z} + (^1/_2 wS_0) \frac{b^2}{3c^2} \cdot z \tag{D}$$

Deflection (maximum deviation from line of supports, at right angles):

$$D = {}^1/_4 a \cdot z + \frac{3a^2 - 2b^2}{144c^2} az^3 \tag{E}$$

Sag (maximum deviation from line of supports, in direction of force):

$$d = {}^1/_4 c \cdot z + \frac{3a^2 - 2b^2}{144c} \cdot z^3 \tag{F}$$

Slope of constant-temperature lines:

$$\frac{\partial T_e}{\partial S} = \frac{AE}{S_0} \tag{G}$$

To Correct for Wind and Ice. Replace a, b, and w by a', b', and w', where:

$$w' = \sqrt{(w+v)^2 + h^2} \tag{H}$$

$$b' = b \cdot \frac{w+v}{w'} \tag{I}$$

$$a' = \sqrt{c^2 - b'^2} \tag{J}$$

Calculations

The practical application of the equations given under "Summary of Formulas" will now be explained.

Initial Value of Parameter. The initial value of z is that value for which T_1' is equal or nearly equal to the maximum permissible tension ("working tension").

To establish the initial value of z, use the relation

$$\coth z = \frac{\Delta}{1 + \frac{1}{6}\left(\frac{a'}{c}\right)^2 \frac{1}{\Delta^2}} \tag{38}$$

where

$$\Delta = \frac{\max. [T_1'] - {}^1/_2 w'b'}{^1/_2 w'c} \tag{39}$$

For nearly horizontal spans, the ratio a'/c may be taken equal to unity (see "Example 2," which follows).

For short spans (see "Example 1"), equation 38 can be replaced by:

$$z = \frac{1}{\Delta} = \frac{^1/_2 w' \cdot c}{\max. [T_1'] - {}^1/_2 w'b'} \tag{40}$$

Unstressed Length. It will be noted that formulas B, C, D, and G involve the quantity S_0, which is the unstressed length at room temperature.

If the tension of the cable is low, the maximum-load minimum-temperature value of S, or that value of S which corresponds to the initial z, can be used in place of S_0 (see "Example 1").

In case of high tension, one can easily estimate the value of S_0 by applying a correction to the maximum-load minimum-temperature value of S, as illustrated in "Example 2."

Tables. The equations in "Summary of Formulas" involve the following functions of z:

$$(z) = \frac{1}{6}\left(z^2 + \frac{z^4}{20}\right),$$

$\coth z$,

$\frac{1}{z}$, z^4, and z^3

These functions are given in table I, for values of z from 0 to 0.5.

Illustrative Examples. The details of the calculations are illustrated in 2 practical examples (see below).

1. Example 1 deals with a proposed span at the Boulder Canyon power plant, and illustrates the calculations for a short span of considerable inclination.

2. Example 2 is based upon published data of an actually existing river crossing, and illustrates the calculations for a long span with a relatively small angle of inclination.

Table II—Sample Calculations, Example 1

Proposed Span at Boulder Canyon Power Plant

	Slack $S - c$		Upper-Support Tension	Effective Tension	Deflection
Wind Load					
Parameter z	$\frac{a'^2}{c} f(z) = 480 f(z)$	$^1/_2 w' S_0 \coth z = 680 \coth z$	$^1/_2 w' S_0 \coth z + {}^1/_2 b'w' =$ last item + 340	$^1/_2 w' S_0 \cdot \frac{1}{z} = 680 \cdot \frac{1}{z}$	$^1/_4 a' \cdot z = 139z$
0.08	0.512	8,520	8,860	8,500	11.1
0.09	0.648	7,580	7,920	7,560	12.5
0.10	0.800	6,820	7,160	6,800	13.9
0.12	1.153	5,690	6,030	5,670	16.7
Light Load					
Parameter z	$\frac{a^2}{c} f(z) = 350 f(z)$	$^1/_2 w S_0 \coth z = 508 \coth z$	$^1/_2 w S_0 \coth z + {}^1/_2 bw =$ last item + 340	$^1/_2 w S_0 \cdot \frac{1}{z} = 508 \cdot \frac{1}{z}$	$^1/_4 a \cdot z = 119z$
0.07	0.286	7,270	7,610	7,260	8.3
0.08	0.373	6,360	6,700	6,350	9.5
0.09	0.473	5,660	6,000	5,640	10.7
0.10	0.584	5,100	5,440	5,080	11.9
0.12	0.841	4,250	4,590	4,230	14.3
0.14	1.144	3,650	3,990	3,630	16.7

Example 1—Proposed Span at Boulder Canyon Power Plant

Given the following:

512,000 circular mil, 1.4 inch diameter, type *HH* hollow copper conductor
E = 16,000,000 pounds per square inch
α = 0.0000096 foot per foot per degree fahrenheit
Maximum tension = 8,650 pounds
w = 1.577 pounds per foot
a = 475 feet
b = 435 feet
Maximum wind load = 12 pounds per square foot
Minimum temperature 10 degrees fahrenheit, maximum 150 degrees fahrenheit
No ice or sleet.

Tension to be measured at upper support with dynamometer.

Wind Load Curve.

h = 12 pounds per square foot times the projected area

$$h = 12 \times 1 \times \frac{1.4}{12} = 1.40 \text{ pounds per foot}$$

$$w' = \sqrt{w^2 + h^2} = 2.11 \text{ pounds per foot}$$

$$\frac{w + v}{w'} = 0.748$$

$c^2 = a^2 + b^2 = 414{,}900$
$c = 644.1$ feet
$b' = 325.3$ feet (by equation *I*)
$b'^2 = 105{,}800$
$a'^2 = 309{,}100$ (by equation *J*)
$a' = 556$ feet

To find the initial value of z:

$$^1/_2 w'b' = 340, \qquad ^1/_2 w'c = 680$$

$$\Delta = \frac{680}{8{,}650 - 340} = 0.082$$

Let z be 0.080, then 0.090, etc. (see table II).

To calculate $^1/_2 w' S_0$: from table II, when z = 0.080,

$S - c = 0.5$
$S = 644.1 + 0.5 = 644.6$ feet

In this case, it will be sufficiently accurate to let

$S_0 = 644.6$ feet. Then, $^1/_2 w' S_0 = 680$ pounds

Remaining calculations are in table II.

Light-Load Curve. To calculate $^1/_2 w S_0$:

$$^1/_2 w S_0 = {}^1/_2 \times 1.577 \times 644.6 = 508 \text{ pounds}$$

Remaining calculations are in table II.

Constant-Temperature Curves. To calculate horizontal interval of the constant-temperature lines for $\Delta\theta$ = 10 degrees fahrenheit:

$$\Delta S = \frac{\partial S}{\partial \theta} \Delta\theta = S\alpha \times 10$$

$\Delta S = 644.6 \times 0.0000096 \times 10 = 0.062$ foot,

or, very nearly, $\Delta S = \frac{6^1/_4}{100}$ foot

To calculate slope of constant-temperature lines:

A = 512,000 circular mils = 0.402 square inch
$AE = 0.402 \times 16{,}000{,}000 = 6{,}430{,}000$ pounds

$$\text{Slope} = \frac{\partial T_e}{\partial S} = \frac{AE}{S_0} = \frac{6{,}430{,}000}{644.6} = 9{,}980 \text{ pounds per foot,}$$

or, very nearly, $\text{slope} = \frac{1{,}000 \text{ pounds}}{0.1 \text{ foot}}$

Construction of Chart. From the data in table II, the tension at the upper support at light load T_1 and at wind load T_1' and the effective tension at light load T_e and at wind load T_e' are plotted against the slack $S - c$.

The 10 degree fahrenheit line is drawn through that point on the T_e' curve which is directly under the 8,650 pounds point on the T_1' curve.

The deflection D is also plotted against the slack. As in most cases, the deflection curves for light load and wind load are found to coincide (see figure 3).

Stringing Chart. The points marked by circles on the T_1 curve in figure 3 comprise the data for the stringing chart.

In this case it is assumed that the cable will be strung at no wind (or, during a relapse of the wind), and that the dynamometer will be used at the upper support. Therefore, the stringing chart should be made up as follows:

Horizontally, plot temperature in degrees fahrenheit.

Vertically, plot the upper-support tension T_1 (light load) in pounds, and, if desired, also the light load deflection D or sag $d = \frac{a}{c} D$.

(Note that the horizontal scale is the temperature of the cable, not air temperature.)

Example 2—Mississippi River Crossing

(Compare with "Mississippi River Crossing of Crystal City Transmission Line," by H. W. Eales and E. Ettlinger, A.I.E.E. Transactions, volume 44, 1925, pages 378–97.)

AE = 11,860,000 pounds
α = 0.00000662 foot per foot per degree fahrenheit
Maximum tension = 33,000 pounds
w = 1.684 pounds per foot
a = 4,279 feet
b = 185.5 feet
Maximum load = 12 pounds per square foot wind and $^1/_2$ inch ice.
Minimum temperature 0 degrees fahrenheit, maximum 120 degrees fahrenheit.

Maximum Load Curve. (Compare with "Example 1.")

$w + v$ = 2.623 pounds per foot $\qquad c$ = 4,283 feet
w' = 3.322 pounds per foot $\qquad b'$ = 146.5 feet
$\frac{w + v}{w'} = \frac{2.623}{3.322} = 0.7896 \qquad a'$ = 4,280 feet

To find initial value of z:

$$^1/_2 w'b' = 240, \qquad ^1/_2 w'c = 7{,}114$$

$$\Delta = \frac{33{,}000 - 240}{7{,}114} = 4.61, \qquad \Delta^2 = 21.25$$

$$\coth z = \frac{\Delta}{1 + \frac{1}{6}\frac{1}{\Delta^2}} = 4.57$$

From table I, the initial value of z = 0.220.

To calculate $^1/_2 w' S_0$: from table III, when z = 0.220,

$S - c = 34.6$
$S = 4{,}283 + 35 = 4{,}318$ feet

This length corresponds to about 0 degree fahrenheit and 33,000 pounds tension. If the tension is released, the cable will shrink by some 12 feet (since

AE = 11,860,000 pounds). If the temperature is raised to 60 degrees fahrenheit, it will gain some 2 feet (see below). One may take:

S_0 = 4,310 feet, $\quad {}^1/_2 w' S_0$ = 7,160 pounds

Remaining calculations are in table III.

Light Load Curve. To calculate ${}^1/_2 w S_0$:

${}^1/_2 w S_0 = {}^1/_2 \times 1.684 \times 4{,}310$ = 3,630 pounds

Remaining calculations are in table III.

Constant-Temperature Curves. To calculate horizontal interval of the constant-temperature lines for $\Delta\theta$ = 10 degrees fahrenheit:

$$\Delta S = \frac{\partial S}{\partial \theta}\Delta\theta = S\alpha \times 10$$

$\Delta S = 4{,}318 \times 0.00000662 \times 10 = 0.286$ foot,

or, very nearly, $\Delta S = \dfrac{28.5}{100}$ foot

To calculate slope of constant-temperature lines:

$$\text{Slope} = \frac{\partial T_e}{\partial S} = \frac{AE}{S_0} = \frac{11{,}860{,}000 \text{ pounds}}{4{,}310 \text{ feet}}$$

$$\text{Slope} = 2{,}750 \text{ pounds per foot} = \frac{11{,}000 \text{ pounds}}{4 \text{ feet}}$$

Construction of Chart. See figure 4.

Appendix I—Effect of Insulators

No attention has been paid so far to the effect of insulators. However, in short dead-ended spans of high voltage lines the influence of the insulators on the mechanical performance of the cable may be appreciable. To gain a general idea of the effect of insulators, a correction will be worked out for the span considered in "Example 1." For the sake of simplicity, only the insulator at the lower support will be taken into account.

Notation. The following notation will be used in this appendix:

a, b = projections of cable span

$\bar{a}, \bar{b}$ = projections of insulator span

$\bar{S}$ = length of insulator

S_0 = unstressed length of cable

w = weight of cable per unit length

$\bar{w}$ = weight of insulator per unit length

$\bar{T}_1$ = tension at cable end of insulator

T_2 = tension at insulator end of cable

$\bar{c} = \sqrt{\bar{a}^2 + \bar{b}^2}, \quad \bar{z} = \bar{a}\bar{w}/2H$

$c = \sqrt{a^2 + b^2}, \quad z = aw/2H$

$g = \sqrt{(a + \bar{a})^2 + (b + \bar{b})^2} - \sqrt{a^2 + b^2}$

Data. Let $\bar{w}$ = 52 pounds per foot, $\bar{S}$ = 14.5 feet. From "Example 1" it follows that:

$a + \bar{a}$ = 475 feet	$c + g$ = 644.1 feet
$b + \bar{b}$ = 435 feet	$S_0 + \bar{S}$ = 644.6 feet, very nearly

Condition for Equilibrium. Obviously, for equilibrium $\bar{T}_1 = T_2$. Using equations B and C, one has:

$$\bar{w}\bar{S}\coth\bar{z} + \bar{w}\bar{b} = wS_0\coth z - wb$$

In this particular case, it is permissible to use the approximate relations

$$\coth z = \frac{1}{z}, \quad \coth\bar{z} = \frac{1}{\bar{z}} = \frac{aw}{\bar{a}\bar{w}}\cdot\frac{1}{z}$$

Solving for z one then has:

$$z = \frac{w[\bar{a}(S_0 + \bar{S}) - (a + \bar{a})\bar{S}]}{\bar{a}[(\bar{w} - w)\bar{b} + w(b + \bar{b})]} \tag{41}$$

Calculations. As a first approximation for $\bar{b}$, one can take

$$\bar{b}_1 = \sqrt{\bar{S}^2 - \bar{a}^2} \tag{42}$$

which is sufficiently accurate to use in equation 41. As a second approximation, one has, by virtue of equation 9,

$$\bar{b}_2 = \bar{b}_1 - \frac{\bar{a}^2}{6\bar{b}_1}\bar{z}^2 \tag{43}$$

The slack can be calculated from the relation

$$S - c = \frac{a^2}{6c}\cdot z^2, \tag{44}$$

where average values of a and c may be used.

By definition of g, one has

$$g = 644.1 - \sqrt{(475 - \bar{a})^2 + (435 - \bar{b})^2},$$

or, approximately,

$$g = \frac{475}{644.1}\bar{a} + \frac{435}{644.1}\bar{b} \tag{45}$$

By assigning arbitrary values to $\bar{a}$, the following table of values is obtained:

$\bar{a}$	11.50	11.70	12.00	12.30	12.60
$\bar{b}_1$	8.83	8.56	8.14	7.68	7.17
$\bar{z}$	0.0637	0.0789	0.1017	0.1244	0.1474
$\bar{b}_2$	8.82	8.55	8.11	7.65	7.03
g	14.43	14.39	14.31	14.21	14.09
$S - c$	0.230	0.353	0.586	0.879	1.230
T_e	7,800	6,300	4,890	4,000	3,370

Graphical Solution. To establish a better comparison between the performances with and without the insulator, it will be assumed that the effective tension at no-wind and 10 degrees fahrenheit is T_e = 6,450 pounds (the same as in figure 3).

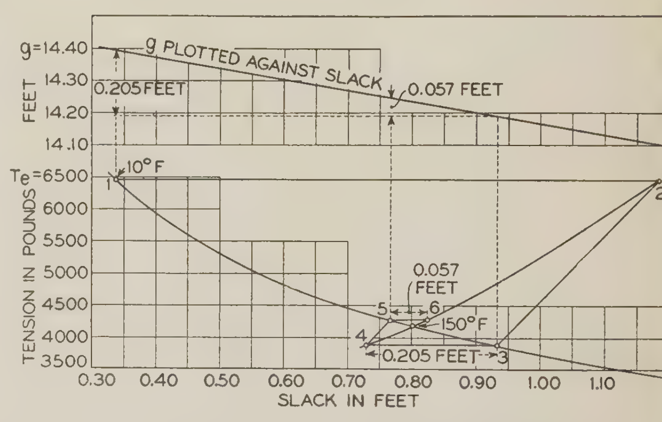

Fig. 5. Study of insulator effect

512,000 circular mil, 1.4 inch diameter, type HH conductor
Horizontal spacing = 475 feet
Vertical spacing = 435 feet
Weight of insulator = 754 pounds

Since c in this case is a variable, one has

$$d(S - c) = dS - dc = \frac{\partial S}{\partial \theta}d\theta + \frac{\partial S}{\partial T_e}dT_e - dc$$

By definition of g,

$$c = 644.1 - g, \qquad dc = -dg,$$

and therefore:

$$d(S - c) = \frac{\partial S}{\partial \theta}d\theta + \frac{\partial S}{\partial T_e}dT_e + dg \tag{46}$$

Table III—Sample Calculations, Example 2

Mississippi River Crossing

	Slack $S - c$		Upper-Support Tension	Effective Tension			Sag
Wind Load and Ice Load							
Parameter z	$\frac{a'^2}{c} f(z) = 4277 f(z)$	$^1/_2 w' S_0 \coth z = 7160 \coth z$	$^1/_2 w' S_0 \coth z + {^1/_2} b' w' =$ last item $+ 240$	$^1/_2 w' S_0 \cdot \frac{1}{z} = 7160 \cdot \frac{1}{z}$			
0.220	34.6	33,070	33,310	32,540			
0.225	36.2	32,360	32,600	31,820			
Light Load							
Parameter z	$\frac{a^2}{c} f(z) = 4275 f(z)$	$^1/_2 w S_0 \coth z = 3630 \coth z$	$^1/_2 w S_0 \coth z + {^1/_2} b w =$ last item $+ 160$	$^1/_2 w S_0 \cdot \frac{1}{z} = 3630 \cdot \frac{1}{z}$	$^1/_4 c \cdot z = 1071 z$	$^3/_{144} c \cdot z^3 = 89 z^3$	Sum of last 2 items
0.205	30.0	17,950	18,110	17,710	219.6	0.8	220.4
0.210	31.5	17,540	17,700	17,290	224.9	0.8	225.7
0.215	33.0	17,140	17,300	16,880	230.3	0.9	231.2
0.220	34.6	16,770	16,930	16,500	235.6	0.9	236.5
Ice Load ($w'' = w + v$)							
Parameter z	$\frac{a''^2}{c} f(z) = 4276 f(z)$			$^1/_2 w'' S_0 \cdot \frac{1}{z} = 5653 \cdot \frac{1}{z}$			See "light load" above
0.215	33.0			26,290			231.2
0.220	34.6			25,690			236.5

At 10 degrees fahrenheit, the slack and tension of the cable are given by point 1 in figure 5. Assuming the span length c constant for the time being and letting $d\theta = 140$ degrees, one follows the path 1–2–3 to the point 3 on the T_e curve. As a result, there is a change in g ($dg = -0.205$ foot) and consequently one follows the path 3–4–5 (see figure 5). Again there is a change in g ($dg = 0.057$ foot), and an infinite process results. However, the final position of the point on the T_e curve is found with sufficient accuracy by drawing a smooth line through the points 2, 6, and 4.

At 150 degrees fahrenheit, the effective tension is seen to be 4,200 pounds, as compared to 3,930 pounds in "Example 1," a difference of less than 300 pounds.

Another calculation was carried out in exactly the same manner, for a much steeper span, 516 feet long. The difference due to the lower insulator at 150 degrees fahrenheit was found to be 550 pounds.

Couclusions. The following conclusions may be drawn concerning the effect of insulators:

1. The insulator has a tendency to act as a counterweight, decreasing the range of variation of tension.
2. In compiling stringing charts, it is generally permissible to neglect the effect of insulators.

Appendix II—Profile Data

In providing for clearances and in designing towers, it is often necessary to calculate a profile of the conductor. Several formulas pertaining to the geometry of the cable will now be derived.

Point of Maximum Deviation. It has been shown that the point of maximum vertical deviation is also the point of maximum normal deviation from the line of supports.

In a horizontal span, the point of maximum deviation from the line of supports is exactly in the middle of the span. In an inclined span, the point of maximum deviation is offset from the middle-point *toward the upper support.* By equations 6, 7, and 29, the horizontal offset is:

$$\frac{a}{2z}\left\{\text{arc sinh}\,\frac{b}{a} - \text{arc sinh}\,\frac{bz}{a \sinh z}\right\}$$

By transforming and making use of equation 8, one has:

$$\text{Offset} = \frac{a}{2z}\,\text{arc sinh}\left[\frac{bz(S-c)}{a^2 \sinh z}\right]$$

or, very nearly:

$$\text{Offset} = \frac{b(S-c)}{2az} \qquad (47)$$

Point of Horizontal Tangency. If the cable has a horizontal tangent, the point of horizontal tangency is the lowest point of the cable.

In a horizontal span, the horizontal tangent occurs exactly in the middle of span. In an inclined span, the point of horizontal tangency moves *toward the lower support.*

By means of equation 47, the point of maximum deviation can be located with considerable accuracy. By equation 29, the distance from the latter point to the point of horizontal tangency can be found at once:

$$\text{Distance from point of maximum deviation} = \frac{a}{2z}\,\text{arc sinh}\,\frac{b}{a} \qquad (48)$$

Angle of Inclination. The cosine of the angle which the cable makes with the horizontal at the upper support is

$$\cos\,(\text{angle of inclination}) = \frac{H}{T_1} = \frac{aw}{2T_1}\cdot\frac{1}{z}$$

SAMPLE CALCULATIONS

Required: clearance to water, Mississippi River crossing in "Example 2," at 32 degrees fahrenheit, ice load, no wind.

(*a*) Data:
From figure 4, at 32 degrees fahrenheit, ice load, no wind:
Sag $= 234$ feet
$T_e'' = 25{,}950$ pounds
$S - c = 33.9$ feet

(*b*) To establish value of z:
In this case,

$$T_e'' = {^1/_2} w'' S_0 \cdot \frac{1}{z}$$

and therefore

$$z = \frac{^1/_2 w'' S_0}{T_e''} = \frac{^1/_2 \times 2.623 \times 4310}{25{,}950} = 0.2178$$

(*c*) To calculate horizontal distances:
Point of maximum deviation to middle-point:

$$\frac{b(S-c)}{2az} = \frac{185.5 \times 33.9}{2 \times 4279 \times 0.2178} = 3.4 \text{ feet}$$

Point of maximum deviation to point of horizontal tangency:

$$\frac{a}{2z}\,\text{arc sinh}\,\frac{b}{a} = \frac{b}{2z}\left[1 - \frac{1}{6}\frac{b^2}{a^2}\right] = 425.7 \text{ feet}$$

Middle point to point of horizontal tangency:

$$425.7 - 3.4 = 422.3 \text{ feet}$$

Point of horizontal tangency to lower support:

$$x_2 = 2{,}139.5 - 422.3 = 1{,}717.2 \text{ feet}$$

(*d*) To calculate elevation of lower support above point of horizontal tangency:

$$y_2 = \frac{a}{2z}\left(\cosh\frac{x_2}{a/2z} - 1\right) = \frac{a}{2z}\cdot\frac{1}{2}\left(\frac{x_2}{a/2z}\right)^2 = 150 \text{ feet}$$

(*e*) Conclusion: at 32 degrees fahrenheit, ice load, the lowest point of the cable is 150 feet below the lower support.

According to H. W. Eales and E. Ettinger (page 396 of "Mississippi River Crossing of Crystal City Transmission Line," A.I.E.E. TRANSACTIONS, volume 44, 1925) this value should be 151 feet.

Steady State Solution of Saturated Circuits

Methods of steady state power calculation developed specifically for: (1) systems having more machines than can be handled conveniently by existing methods; and (2) systems consisting of a line with magnetically saturated synchronous machines at both ends are outlined in this paper. Two general methods are given: (1) that involving the use of equivalent reactance or impedance, and (2) that involving the superposition of current diagrams. Methods of determining the equivalent reactance and impedance of any unknown system from measurements at the terminals of that system, whether magnetically saturated or not, also are given. When a complete solution is desired, superposition of current diagrams of saturated circuits is shown to be better than the method involving the use of either equivalent reactance or impedance.

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THE METHODS of steady state power calculation here outlined are the outgrowth of 2 specific problems. One problem was to find the steady state limit of a system (figure 14) having more machines than could be handled by existing methods without detrimental preliminary simplification. The other problem was to find the steady state limit of a system consisting of a transmission line with synchronous machines at both ends, accurately evaluating the effects of magnetic saturation on power and on voltage.

In steady state problems changes are assumed to take place slowly enough so that inertia forces can be neglected. Consequently any relative shift in phase position of the voltages in different parts of a system can be neglected; and if the voltage is known for all currents and power factors at any point of a system, the stability of any steady load connected to the system at that point can be calculated without knowing more about the system. The current diagram (figures 8 and 9) was adopted as the best way to show the relation between these variables. It must be remembered that if the action of voltage regulators is to be considered, a transient and not a steady state problem will result. Two methods of calculating stability from a current diagram are discussed. One involves the use of equivalent impedance, and the other involves the placing of one diagram upon another.

The solution of the first problem was accomplished by the use of equivalent impedances calculated from current diagrams, and the solution of the second problem was obtained best by the superposing of current diagrams. Although the method of superposing current diagrams to take account of saturation is given only small space here because of its simplicity, it is thought to be the best method for most problems, as it is rigorous when test data for the machines are available, and it enables a complete solution to be obtained with less effort than by the use of equivalent reactances.

EQUIVALENT REACTANCE

If the terminals of a power system are available, but nothing is known about the system behind the

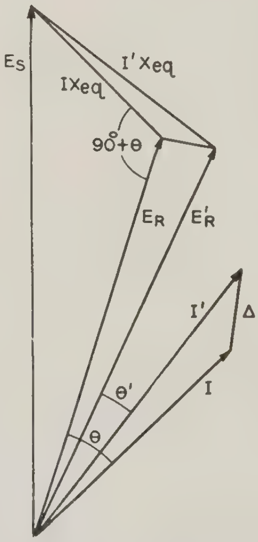

Fig. 1. Vector diagram with respect to sending end with Es constant

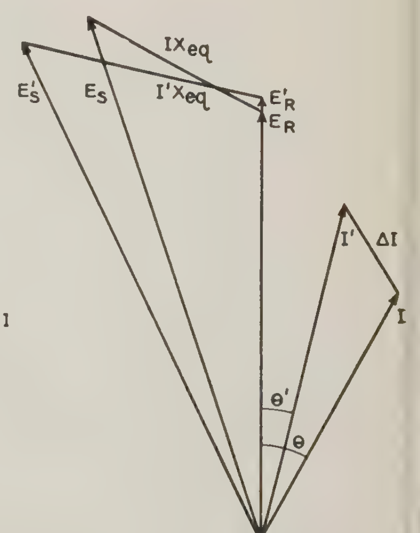

Fig. 2. Vector diagram with respect to receiving end with Es constant

Note that ΔI does not equal the ΔI of figure 1 even though the diagram is for the same set of conditions

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* Now with Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

erminals, it is possible to make a simple test to etermine the maximum steady state load that can e connected to the terminals.

In principle the test consists of finding a combination of impedance and fictitious internal voltage hat will give the same magnitude of terminal oltage as the actual system, both before and after n arbitrary increment of load. There will be an nfinite number of such combinations unless (1) the mpedance angle is restricted to a definite value, or 2) two increments of load are considered, that is, 3 instead of 2 conditions of system operation. If, n the first case, the increment of load is small and 90 degree impedance angle is chosen, equivalent eactance,[1] X_{eq}, is obtained; and if, in the second ase, the increments of load are small, equivalent mpedance, Z_{eq}, is obtained. The equivalent reactance or impedance and the voltage behind it robably will be different for different increments f load and will not be a true representation of the ystem for transient calculations, since equivalent alues do not always give true angular displacements. Nevertheless, they lead to valuable simplifications in steady state calculations and to an exact method of testing synchronous machines to determine their steady state stability characteristics, ncluding effects of magnetic saturation.

Equivalent Reactance From Vector Diagrams

Equations for an equivalent reactance in terms of the initial and final circuit conditions can be obtained from the vector diagrams of figure 2. Considering the initial conditions, and expressing E_S (for definitions of all symbols see list at end of paper) in terms of the 2 opposite sides and included angle of the voltage triangle,

$$E_S^2 = (IX_{eq})^2 + E_R^2 - 2E_RIX_{eq}\cos(90° + \theta)$$

Similarly, for the final conditions,

$$(E_S')^2 = (I'X_{eq})^2 + (E_R')^2 - 2E_R'I'X_{eq}\cos(90° + \theta')$$

1. For all numbered references see list at end of paper.

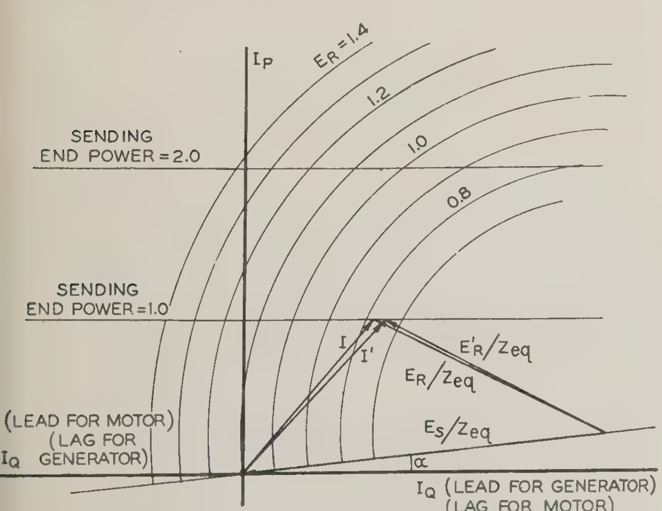


Fig. 3. Sending end current circle diagram, with loci of constant sending end power; E_S = 1.1 = constant

Equating the 2 expressions, since the magnitudes of E_S and E_S' are equal,

$$[(I'X_{eq})^2 - (IX_{eq})^2] + [(E_R')^2 - E_R^2] - [2E_R'I'X_{eq}\sin\theta' - 2E_RIX_{eq}\sin\theta] = 0$$

$$X_{eq}^2[(I')^2 - I^2] - 2X_{eq}[E_R'I'\sin\theta' - E_RI\sin\theta] + [(E_R')^2 - E_R^2] = 0 \quad (1)$$

$$X_{eq}^2[\Delta(I^2)] - 2X_{eq}[\Delta(RVA)] + [\Delta(E_R^2)] = 0 \quad (2)$$

$$X_{eq} = \frac{\Delta(RVA)}{\Delta(I^2)} \pm \sqrt{\left[\frac{\Delta(RVA)}{\Delta(I^2)}\right]^2 - \frac{\Delta(E_R^2)}{\Delta(I^2)}} \quad (3)$$

If curves of reactive volt-amperes and of voltage squared be plotted against current squared for the

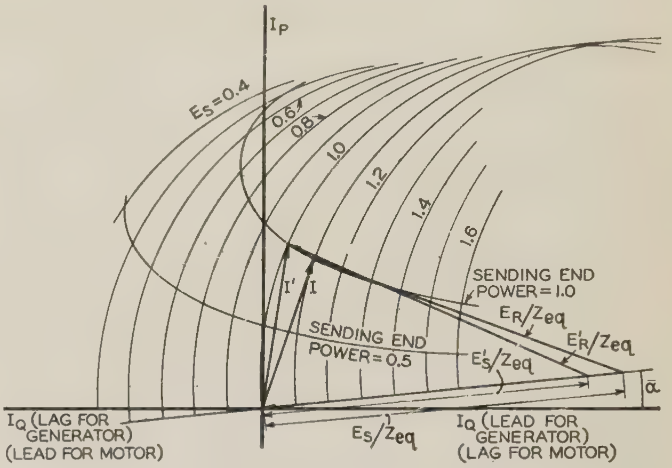


Fig. 4. Sending end current circle diagram, with loci of constant sending end power; E_R = 1.0 = constant

type of system change considered, and the slopes of these curves designated as S_{RVA} and S_{EE}, the expression becomes,

$$X_{eq} = S_{RVA} \pm\sqrt{S_{RVA}^2 - S_{EE}} \quad (4)$$

This gives one means of determining exactly the equivalent reactance for any condition for which the proper test data are available, subject to the difficulty that at certain points of the diagram the slopes may pass through infinity, making it necessary to take a small difference between 2 large quantities.

It is interesting to note that for constant power factor and small changes equation 3 can be converted to equation E-6 of reference 1. It is interesting to note also that X_{eq} is not the same as $X_{d(eq)}$ (equivalent direct axis reactance, see reference 1) of a salient pole machine, but is the X_{eq} that would be obtained if a salient pole machine were tested as though it had a round rotor.

Another method, less direct, but easier to picture over a wide range of conditions, is the current diagram method to follow.

Equivalent Reactance or Impedance From Current Diagrams

The behavior of a circuit consisting of an impedance between 2 infinite busses can be represented by a current diagram which will consist of circles

and will appear as shown in figures 3 and 4 or figures 5 and 6, depending on whether the current is plotted with respect to the sending or receiving end voltage and on whether the sending or receiving end voltage is varied.[2] If similar diagrams be plotted for a saturated circuit such as a synchronous machine or for a network, they may not consist of circles (see figure 8), but often they are near enough to circle diagrams so that over an appreciable range they may be replaced approximately by circles.

It can be shown that any circuit can be replaced by another one, as far as steady state is concerned, if the 2 circuits have identical current diagrams over the range of operation considered, where "identical" refers to the spacing as well as the shape of the curves of constant voltage. Therefore, in order to find equivalent reactance or impedance from a current diagram, it is necessary only to find the simple reactance or impedance, the circle diagram for which is most nearly identical to the current diagram of the actual circuit in the region being considered. Just when the 2 are most similar will depend on the direction of the current increment being considered.

Graphical constructions for obtaining equivalent impedances and reactances from a current diagram are shown in figure 7. Two examples are considered: (1) to obtain equivalent reactance or impedance with a current increment along the locus of constant voltage, and (2) to obtain equivalent reactance or impedance with a current increment along the locus of constant power.

In the first example, the 3 points (such as A, B, and C in figure 7) chosen to represent the given

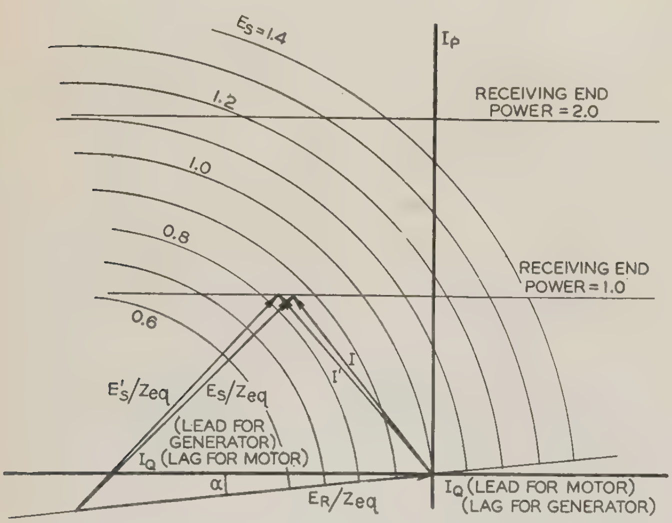


Fig. 5. Receiving end current circle diagram, with loci of constant receiving end power; E_R = 1.0 = constant

region are chosen along a locus of constant voltage, and a circle is drawn through them. The impedance and internal voltage that would give this same circle are then the equivalent impedance and fictitious internal voltage that represent the system. In figure 7, the center of the circle is at D, the magnitude of the impedance is such that $DO = |E_T| \div |Z|$,

Table I—Comparison of Calculated and Test Pull-Out Data for a Laboratory Setup With Saturated Machines

Test (1 and 2) and Calculated (3 to 6) Conditions	Per Cent Margin	Per Cent Voltage at Pull-Out
1. Normal power = 9.5 kw at 130 volts		
2. P_{max} on basis of test = 11.8 kw at 111 volts	24.2	85.4
3. P_{max} on basis of A.I.E.E. synchronous reactance = 10.5 kw at 110 volts	10.5	84.6
4. P_{max} on basis of X_{eq} at normal operating point = 12.7 kw at 107 volts	33.7	82.2
5. P_{max} on basis of X_{eq} at pull-out point = 11.5 kw at 109 volts	21.0	83.8
6. P_{max} on basis of $\frac{\text{operating } X_{eq} + \text{pull-out } X_{eq}}{2}$ = 12.0 kw at 109 volts	26.3	83.8

Line 1 corresponds to point P in figure 8; line 2 to curve B; line 3 to curve E; line 4 to curve C; and line 5 to curve D.

See description under figure 8 for conditions of test. Equivalent reactances used were those corresponding to current increments along lines of constant power, and were read from the dotted curves of figure 8.

the angle of the impedance is θ_2, and the magnitude of the internal voltage is such that $DA = |E_{NL}| \div |Z|$. (Compare figure 6.) If an equivalent reactance is desired instead of an equivalent impedance only 2 points should be chosen to represent the region; and of the infinite number of circles possible through these 2 points, the one with a center on the axis of quadrature current should be chosen.

In the second example, the 3 points (such as L,

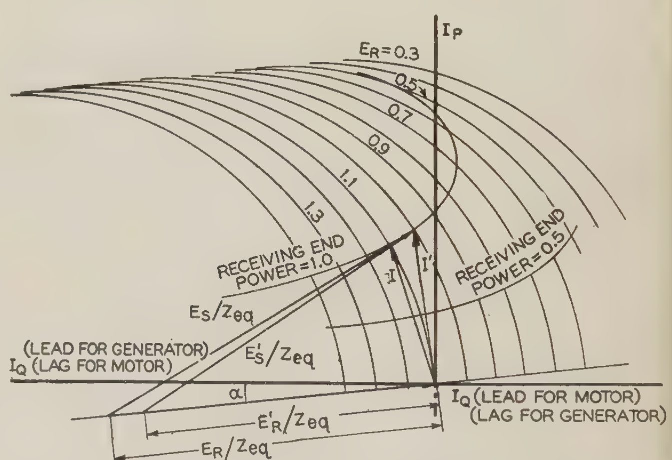


Fig. 6. Receiving end current circle diagram, with loci of constant receiving end power; E_S = 1.1 = constant

M, and N in figure 7) are chosen along a locus of constant power, and by a "cut and try" process the points G, H, and J are located so that $GL = JM = HN$ when G, J, and H are on a straight line through the origin and $GO \div |E_T| = JO \div |E_T''| = HO \div |E_T'|$. The "cut and try" process can be simplified by considering only 2 points, such as L and N, on the constant power curve and making GL perpendicular to the curve ACL, still keeping $GL = HN$ and $|E_T| \div GO = |E_T'| \div HO$. The magnitude of the equivalent impedance is such that $GO = |E_T| \div |Z|$, and the angle of Z is θ_1. If an equivalent reactance be desired, θ_1 must be 90 degrees and consequently only 2 points, such as

L and N, can be considered if a singular solution be desired.

If the choosing of different pairs or triads of points to represent a given region causes appreciable variation in the equivalent impedance obtained, as in the case of complex or saturated circuits, the points chosen should be as nearly as possible along the

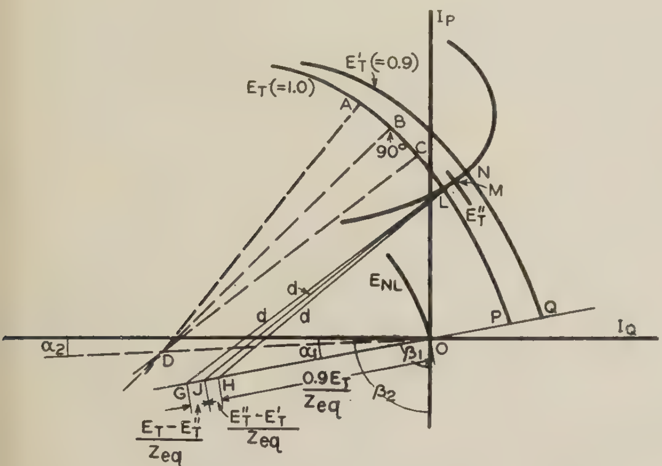


Fig. 7. Graphical means of obtaining equivalent reactance

The 3 curves of constant voltage and the 1 curve of constant power are the assumed data from which the reactance is to be obtained

increment of current expected during the changes for which the equivalent system is used to represent the actual system.

Reactances obtained by the foregoing procedure are the same as would be obtained from equation 3. The constructions were extended to include impedances because, in general, accuracy over a greater region can be obtained from an equivalent impedance than from an equivalent reactance.

Equivalent Reactance in Synchronous Machine Steady State Calculations

Considering equivalent reactance as a constant instead of a variable in circuits where synchronous machines constitute most of the system reactance is not always justifiable if an accurate answer be desired. However, in special cases the desired accuracy may be obtained with a constant equivalent reactance if it is chosen properly to represent the actual varying reactance for the system changes being considered. An illustration of this can be taken from a typical system involving saturated machines which actually was set up and tested in the laboratory of the California Institute of Technology. Comparisons of test and calculations are shown by curves B, C, D, and E in figure 8 and by table I. It may be noted that the margin between the power at the assumed normal operating condition at point P and the maximum power was 24 per cent with constant excitation. However, calculation of this margin starting with the test current, voltage, and

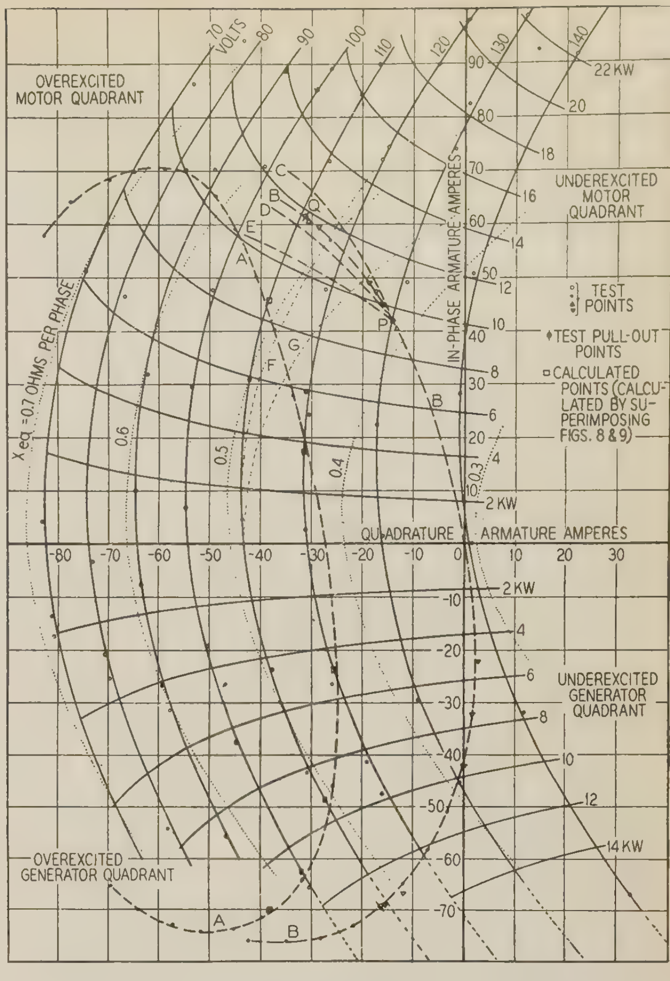


Fig. 8. Current diagram for laboratory alternator; field current = 12 amperes; 60 cycles

Alternator name plate rating: 15 kva, 110 volts, 1,200 rpm, 60 cycles

Curve A is for pulling apart of 2 identical alternators, one having a field current of 6 amperes and the other 12 amperes

Curve B is same as Curve A except that both machines have field current of 12 amperes and there is a series impedance of 0.108 + j 0.64 ohms between the 2 machines

Curves C, D, and E are calculated pull-out curves assuming constant field excitations and: (C) X_{eq} corresponding to point P; (D) X_{eq} corresponding to point Q; (E) A.I.E.E. synchronous reactance

Curve F is curve of constant voltage behind Potier reactance (assuming $R + jXp = 0.025 + j\,0.18$ ohms per phase)

Curve G is a curve of constant direct axis component of the voltage behind Potier reactance

Curves of constant X_{eq} are for constant power current increments

power factor at point P and using different values of X_{eq} gave the variation in margin and voltage dip shown in table I. The only reasonably accurate calculation is that of line 6 where an average value of X_{eq} was used.

Values of X_{eq} in table I were read from the dotted curves in figure 8, which were calculated by the method of equation 4 using current increments along lines of constant power. The justification for assuming current increments along lines of constant power is that for both motors and generators pull-out usually occurs when power is constant during an increase in displacement, and this is true regardless of the amount of system reactance. Consequently, the saturated synchronous reactance effective at pull-

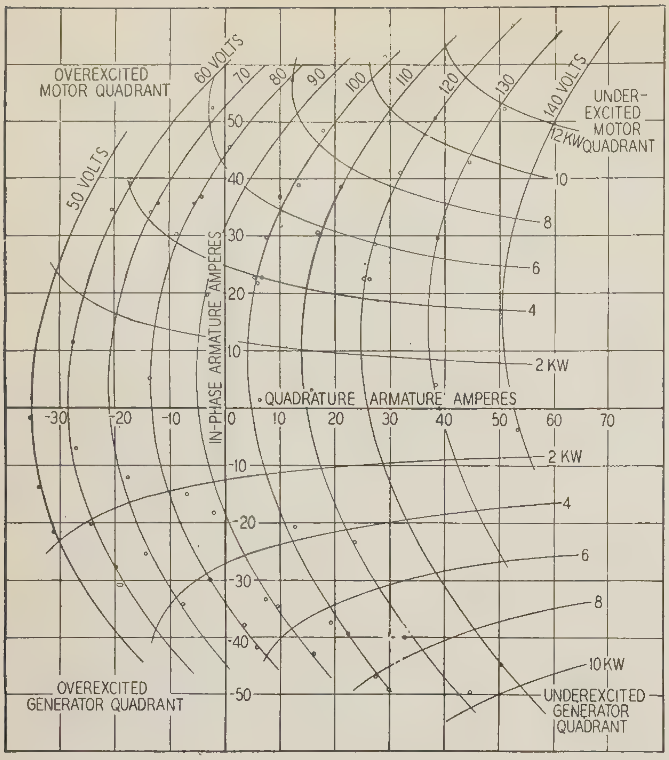


Fig. 9. Current diagram for laboratory alternator similar to that of figure 8; field current = 6 amperes; 60 cycles

out is that corresponding approximately to an increment of current along the locus of constant motor power.

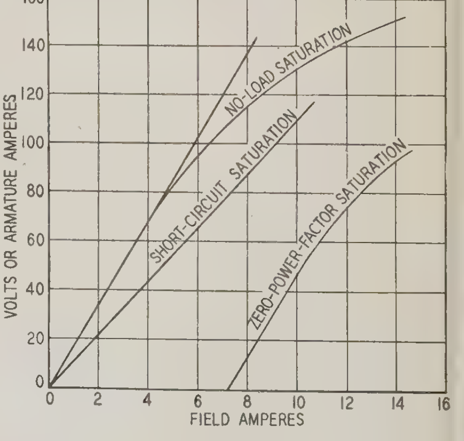
Tests of Equivalent Reactance of a Synchronous Machine. An exact test for the equivalent reactance of a synchronous machine can be made if 2 machines can be coupled together with an adjustable angle coupling and connected as in figure 11. Data needed are those necessary to plot a current diagram, which consist of reactive volt-amperes and current (or power) for different terminal voltages and field currents. By adjusting the bus voltage supplying the losses, it is possible to obtain data for any desired voltage. Output power can be obtained by subtracting losses from input power. The equivalent reactance for constant output power then can be calculated from equation 3, or by the graphical method of figure 7. If curves of constant equivalent reactance be plotted, as in figure 8, accuracy will be improved.

Several approximate methods of testing equivalent reactance have been suggested.[1] When zero power factor saturation curves are available, the method suggested by J. W. Butler in a discussion of the paper listed in reference 1 appears to be best, although calculations made in collaboration with L. A. Kilgore show that using direct axis component, rather than numerical value of voltage behind leakage reactance, gives more conservative and usually more accurate results. When only a no-load saturation curve is available, the method of reference 5 (correcting demagnetizing reactance by the ratio of slope of saturation curve to slope of air gap line) is only slightly less accurate than Butler's method, although the same qualification should be made that direct axis component of voltage behind leakage reactance be used as the voltage at which the slopes are taken. Curve *F* on figure 8 shows, for a salient pole laboratory machine, how a curve of voltage behind Potier reactance follows curves of constant equivalent reactance, and curve *G* shows the same comparison for the direct axis component of the voltage behind Potier reactance. Potier reactance voltage drop (IX_p) was taken as 25 volts at an armature current of 80 amperes, and resistance drop was taken as 3.5 volts for the same armature current. Round rotor theory was used in obtaining the direct axis.

Equivalent Reactance in System Steady State Calculations

In the preceding portion of the paper it was shown that the equivalent reactance of a synchronous machine was a reactance the circle diagram for which was most similar to the current diagram of the machine for the region or for the current increments being considered. Similarly, any unknown system behind a set of terminals must have an equivalent reactance, as the synchronous machine has been treated only as such a system. This principle can be used to solve approximately any system made up of an impedance with shunt loads at various points between its 2 extremities. The process is to represent the first shunt load plus the impedance preceding it by an equivalent impedance without a shunt load, and then repeat the process, eliminating a shunt load with each repetition, until the system to the load is represented by a single impedance. Because of the variation of equivalent impedance with direction of current increment, it is necessary to estimate carefully the direction and magnitude of the expected increment in each part of the system, and then choose each equivalent reactance corresponding to the proper current increment. One advantage of this

Fig. 10. Saturation curves of the laboratory alternator of figures 8 and 9; 60 cycles



method of eliminating shunt loads is that in order to replace a line with a complex shunt load by a reactance, only the current-voltage characteristic of the load need be known.

By means of this process, an impedance with a

shunt load at the receiving end is replaced by an equivalent impedance without a shunt load. By carrying on this process step by step, any circuit without loop connections can be reduced to a simple impedance.

Test for Equivalent Reactance of a System. A means of determining the approximate magnitude of the equivalent impedance of a system is to throw on a low power factor load, such as the starting current of a synchronous machine, and measure the change of voltage produced. Assuming that the low power factor current has the same angle as the equivalent impedance of the system, the magnitude of the equivalent impedance is simply $|\Delta E| \div |\Delta I|$. For example, if in figure 7 the current increment were PQ instead of LN, then $|Z_{eq}| = (E_T' - E_T) \div GH = (E_T' - E_T) \div PQ = |\Delta E| \div |\Delta I|$. Because of the action of the regulators, the maximum change of voltage will be less than it would have been if the transient reactance had been allowed to decay to synchronous reactance. Therefore, if the regulators have appreciable effect on maintaining voltage, they should be blocked, or the measurements no longer will apply to steady state conditions.

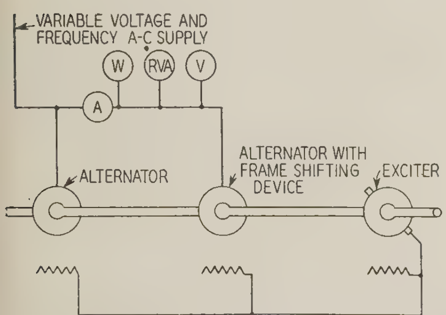


Fig. 11. Diagram of connections for test of equivalent reactance

A—ammeter
W—wattmeter
RVA—reactive volt-ampere meter
V—voltmeter

A means of accurately measuring a small dip in voltage, such as that produced by a motor starting current on an ordinary distribution system, is to use a vacuum tube for a voltage cut-off device so that an oscillograph can be made to show only the top of a voltage wave. One suitable circuit that will enable a voltage dip of 3 per cent to be shown as one centimeter change of deflection is that shown in figure 12.

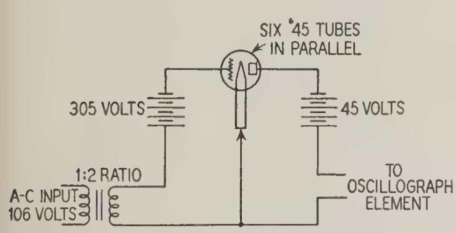


Fig. 12. Vacuum tube amplifier circuit for measuring voltage dip with oscillograph

Two tests have been made on actual systems to check the equivalent reactances as calculated by the current diagram method. The first system is that of the Southern California Edison Company. The tests were made at Colton, which is distant about 50 miles of 66 kv network from the main 220 kv substation, by switching on and off a 30,000 kva synchronous condenser and measuring the maximum ratio of $|\Delta E|$ to $|\Delta I|$. The reactance measured was 0.25 per unit; using the simplified system of figure 13, the reactance calculated was 0.32/33°,

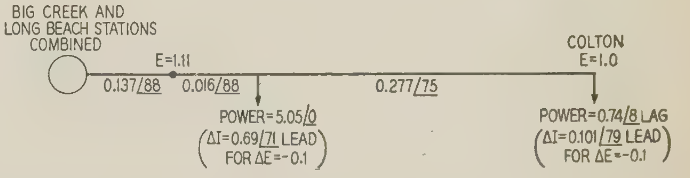


Fig. 13. Simplification of Southern California Edison Company system; 100,000-kva 66-kv base

which is as good a check as could be expected considering the complexity of the system. The series reactance, to Colton, calculated without correction for the effect of shunt load, would have been 0.42/5°. Thus the load actually made the system more nearly

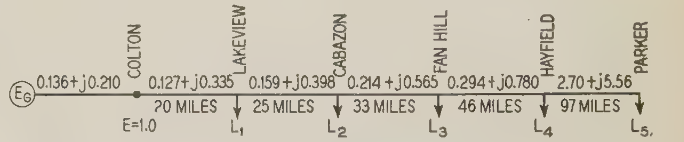


Fig. 14. Construction system of the Metropolitan Water District of Southern California at time of tests of X_{eq}; 100,000-kva 63-kv base

L_1, L_2, etc., designate loads at various points
I_1, I_2, etc., designate currents to respective loads

$L_1 = 0.00400 + j0.01030$ kva $\quad \Delta I_1 = 0.00023 + j0.00474$ for $\Delta E = -0.1$
$L_2 = 0.00575 + j0.00225$ kva $\quad \Delta I_2 = 0.00035 - j0.00060$ for $\Delta E = -0.1$
$L_3 = 0.01550 + j0.00045$ kva $\quad \Delta I_3 = 0.00060 + j0.00559$ for $\Delta E = -0.1$
$L_4 = 0.00620 + j0.00160$ kva $\quad \Delta I_4 = 0.00019 - j0.00150$ for $\Delta E = -0.1$
$L_5 = 0.00320 + j0.00350$ kva $\quad \Delta I_5 = 0.00021 + j0.00017$ for $\Delta E = -0.1$

an infinite bus than the same system would have been without the load.

The second system, shown in figure 14, is that built by the Metropolitan Water District of Southern California to furnish construction power along the route of the Colorado River Aqueduct. Tests were made by switching on and off a 5,000 kva synchronous condenser at Parker. The reactance measured was 8.05/65°, the reactance calculated was 8.67/68° and the series reactance (shunts neglected) was 8.00/81°.

It might be noted that both tests give lower values of reactance than do the calculations, as expected, because the effect of the regulators is included in the tests but not in the calculations; also it can be noted that the effect of regulators and machine saturation is greater for the first system than for the second, as expected, because of the smaller proportion of line reactance.

Current Diagram Method of Steady State Power Calculations

Previous sections of the paper have dealt with equivalent reactance because it is a customary and

simple procedure to represent a machine by reactance. However, steady state problems often can be solved more easily and more completely by the use of current diagrams than by the use of reactances when the effect of saturation is appreciable and is to be evaluated accurately. The general method of determining the behavior of current with changes in power is merely to superpose the current diagram of one end of any circuit on the current diagram of the other end and select points of equal voltage.[6,7] As an example, suppose the laboratory

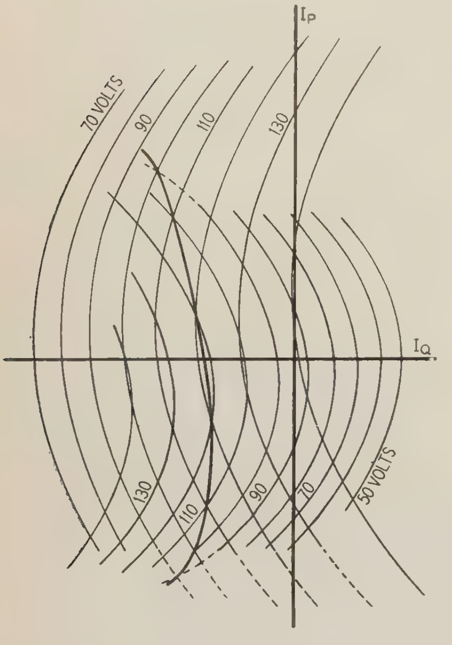


Fig. 15. Simultaneous solution of the 2 current diagrams of figures 8 and 9

alternator, for which the current diagram with a field current of 12 amperes is shown in figure 8, is connected directly to a duplicate machine with a field current of 6 amperes, the current diagram for 6 amperes being shown in figure 9. To find the behavior as the angular displacement is increased, it is necessary only to rotate the motor current diagram 180 degrees about the origin (i. e., plot it as in figure 4) and superpose it on the other diagram. The points represented by the intersection of lines of equal voltage, as shown in figure 15, then give the behavior of the current and voltage as functions of power output.

In essence, this process of superposing diagrams and selecting points of equal voltage is similar to the method of plotting curves and finding their intersection that is sometimes used to solve simultaneous equations. In other words, a current diagram is a plot of an equation between vector current and scalar voltage of the terminals of a system. Pull-out occurs where the current locus becomes parallel to the lines of constant power. Comparison between a curve calculated in this manner and an actual test curve is shown in figure 8, where the calculated points are shown by squares and the test curve is the dashed curve A. The test curves were checked 3 different ways: (1) by coupling the motor shaft to the generator shaft and varying load by means of a frame shifting device as was done for the circle and dot test points in figure 8; (2) by loading with a d-c generator feeding back to a d-c bus as was done for the inverted triangle test points in figure 8; and (3) by loading with a d-c generator supplying resistance load as was done for the 4 triangular test points in figure 8.

If series reactance or shunt load had been placed between the 2 machines, it would have been necessary to correct the diagram of one or the other machine to take account of the intermediate system so that the 2 final diagrams to be superposed would be those of the 2 ends of the system with respect to voltage at the point of division.

The outstanding feature of a current diagram solution made as just outlined is that saturation is taken into account completely and accurately; any method of steady state calculation using equivalent reactance must make use of a step-by-step solution, in order to be exact, because equivalent reactance is not constant.

Approximations assuming constant equivalent reactance are compared with test data in figure 8 and table I. These comparisons show that, although equivalent reactance takes exact account of saturation, a judicious choice of the operating condition determining equivalent reactance must be made in order to assure reasonable accuracy of the results.

Symbols

I = current
I_P = power component of current
I_Q = quadrature component of current
E_S = sending end voltage
E_R = receiving end voltage
E_T = terminal voltage
E_G = generated or internal voltage of a generator
E_M = generated or internal voltage of a motor
Z = impedance = $r + jx$
Z_{eq} = equivalent impedance (see text for definition)
X_{eq} = equivalent reactance (see text for definition)
$X_{d(eq)}$ = direct axis equivalent reactance
β = impedance angle = $\tan^{-1}\frac{x}{r}$
α = $90° - \beta$
θ = power factor angle
δ = displacement angle between E_S and E_R
RVA = reactive volt-amperes
$|Z|$, $|E|$, etc., denote magnitude of Z, E, etc. This symbol is used where the meaning is not clear from the context
I', E', etc., denote conditions after a change
Δ denotes an increment

References

1. Equivalent Reactances of Synchronous Machines, Crary, Schildneck, and March. Elec. Engg. (A.I.E.E. Trans.), v. 53, Jan. 1934, p. 124–32.

2. Electrical Characteristics of Transmission Circuits, W. B. Nesbit. Westinghouse Technical Night School Press, 1920.

3. Steady State Stability in Transmission Systems, E. Clarke. A.I.E.E. Trans., v. 45, 1926, p. 22–41.

4. Power Limits of Synchronous Machines, E. Clarke and R. G. Lorraine. Elec. Engg., v. 52, Nov. 1933, p. 780–7 (A.I.E.E. Trans., v. 53, 1934, p. 1802–9).

5. Discussion, E. Clarke. A.I.E.E. Trans., v. 45, 1926, p. 93.

6. Equivalent Circuits in Stability Studies, O. G. C. Dahl and A. E. Fitzgerald. Elec. Engg. (A.I.E.E. Trans.), Sept. 1934, v. 53, p. 1272–82.

7. Power System Transients, V. Bush and R. D. Booth. A.I.E.E. Trans., v. 44, 1925, p. 80–97.

Report of the Board of Directors

The board of directors of the American Institute of Electrical Engineers presents herewith to the membership its fifty-first annual report, for the fiscal year ending April 30, 1935. A general balance sheet showing the condition of the Institute's finances on April 30, 1935, together with other detailed financial statements, is included herein. This report contains a brief summary of the principal activities of the Institute during the year, more detailed information having been published from month to month in ELECTRICAL ENGINEERING.

Celebration of Fiftieth Anniversary of the Institute

A fiftieth anniversary meeting was held on Monday morning, June 25, 1934, during the annual summer convention at Hot Springs, Va., immediately after the annual business meeting of the Institute. This was the climax of the celebration of the fiftieth anniversary of the founding of the Institute, in 1884, which had included the publication of the anniversary (May 1934) issue of Electrical Engineering, and the holding of various anniversary meetings by the Sections and Branches. The 2 anniversary addresses were delivered by Dr. W. E. Wickenden, president, Case School of Applied Science, and Dr. William McClellan, past-president of the Institute.

Board of Directors' Meetings

During the year, the board of directors held 5 meetings, 4 in New York City, and one at Hot Springs, Va. The executive committee meetings in December and March were held in place of regular meetings of the board. Information regarding many of the more important activities of the Institute which have been under consideration by the board of directors and the committees is published each month in the section of Electrical Engineering devoted to "News of Institute and Related Activities."

National Conventions

Three national conventions were held during the year, and a brief report on each follows.

Summer Convention. The fiftieth summer convention was held at Hot Springs, Va., June 25–29, 1934. Thirty papers were presented during the 7 technical sessions. Other parts of the convention were the annual business meeting of the Institute, fiftieth anniversary meeting, conference of officers, delegates, and members, golf and tennis tournaments, president's reception and dance, banquets, and ladies events. The Lamme Medal for 1933 was presented to Dr. Lewis B. Stillwell, past-president of the Institute. The registration was 351.

Annual Meeting. The annual business meeting of the Institute was held on Monday morning June 25, as part of the opening session of the summer convention. The annual report of the board of directors for the fiscal year ending April 30, 1934, was presented in abstract, and the committee of tellers reported upon the election of officers for the administrative year beginning August 1, 1934. President-elect Johnson responded with a brief address.

Pacific Coast Convention. The twenty-second Pacific Coast convention of the Institute was held in Salt Lake City, Utah, September 3–7, 1934. The registration was 232, and the attendance at the technical sessions averaged more than 100. The technical program included 25 papers at 5 sessions, and, in addition, 12 student papers at 2 regular sessions held for their presentation and discussion. Especially attractive entertainment events and trips, as well as the excellent technical program, kept enthusiasm high throughout the convention.

Winter Convention. The twenty-third winter convention, held in New York City, January 22–25, 1935, was opened by a brief general session including an address of welcome by C. R. Jones, chairman of the winter convention committee, an address by President Johnson entitled "The A.I.E.E. as an Educational Institution," read by Vice President W. H. Timbie, and a brief announcement regarding the technical sessions by R. N. Conwell, chairman of the technical program committee. During the 12 sessions held on the first 3 days, 53 papers were presented. At an evening session, the Edison Medal was presented to Dr. Willis R. Whitney, the John Fritz Medal, awarded to the late Frank J. Sprague only a few days before his death, was presented to his son Robert C. Sprague, and A. L. Powell, president of the Illuminating Engineering Society, gave a demonstration lecture on "Artificial Light—The Engineers' Greatest Gift to Mankind." Numerous inspection trips aroused an unusual amount of interest. The registration was 1,114.

District Meetings

Two District meetings were held during the year, and a brief report on each follows.

North Eastern District Meeting. The tenth annual North Eastern District meeting was held in Worcester, Mass., May 16–18, 1934, with a registration of 337, including more than 100 Enrolled Students, 4 sessions at which 13 technical papers were presented, a student session including 7 papers, a fiftieth anniversary address by Past President Charles F. Scott, an address on "An Insight Into the Workings of the Institute," by Vice President J. Allen Johnson, an illustrated lecture on high voltage

by Dr. Robert J. Van De Graff, inspection trips, and entertainment events.

South West District Meeting. The fifth South West District meeting was held in Oklahoma City, Okla., April 24–26, 1935. The total registration was 571, including about 160 students. The program included 12 papers, a demonstration lecture on d-c power transmission, a symposium on engineering education, 12 additional papers by students, inspection trips, and entertainment events.

Sections

Nearly all Sections carried on a normal amount of activity during the year, and efforts to develop plans to maintain and increase the interest of their members resulted in the adoption by a few of them of methods which have been even more successful than anticipated.

The Portland Section organized 3 technical committees: communication, industrial power application, and transmission and distribution, which have held 6, 9, and 6 meetings, respectively, with an average attendance of about 16.

Since early in 1934, the San Francisco Section has held special technical meetings, devoted mainly to informal discussions, between the regular Section meetings. Thus, it has been practicable to plan regular meetings with well balanced programs that have been attractive to a large number of members. A comprehensive report upon the new plan and its place in the activities of the Section was published on page 454 of the April 1935 issue of Electrical Engineering.

The Boston and Lynn Sections held competitions among their members in the writing of papers, choosing 3 papers from each for presentation at a joint meeting. Three prizes based upon the contents of the papers as well as upon the presentations were awarded.

The Toledo Section has been holding "forum meetings" between the regular technical meetings and having addresses by outstanding speakers. It also has had a brief talk on fundamental electrical theory, by a member of the Section, during the first part of each regular meeting.

The New York and Chicago Sections continued their technical group activities with interest well maintained.

The Pittsfield and Schenectady Sections held their annual competition among their younger members.

In co-operation with the national membership committee, the Sections have induced many former members to become reinstated—697 since August 1, 1934.

Early in March, the Sections of the Institute were urged by the committee on student selection and guidance of the Engineers' Council for Professional Development to co-operate with the sections of other engineering societies and with local engineering organizations in the establishment of joint committees which should offer sympathetic advice to boys thinking of entering engineering, and to high school principals, vocational counselors, and others interested in assisting boys in the choice of their careers.

Student Activities

Practically all of the Branches carried on a normal amount of activity, and many had considerable numbers of student papers presented at their meetings.

During the fiscal year, new Branches were organized at Brown University, Providence, R. I., Johns Hopkins University, Baltimore, Md., Tufts College, Medford, Mass., and Union College, Schenectady, N. Y., bringing the total number of Branches to 117.

Students made important contributions to the success of the Pacific Coast convention and the District meetings held in Worcester, Mass., and Oklahoma City, Okla., by their enthusiastic participation in the technical programs and in other events. They conducted 1 session with 7 papers in Worcester, 2 sessions with 12 papers at the Pacific Coast convention, and 2 sessions with 12 papers in Oklahoma City.

About 50 per cent of the Enrolled Students whose terms of enrollment expired on April 30, 1935, applied for admissions as Associates.

During the past fiscal year, 1,983 Students were enrolled, bringing the total number enrolled on April 30 to 3,806, the largest number on that date since 1931 (3,813).

The Sections and Branches have in many cases co-operated closely, and several developments in Section activities described briefly in the paragraphs above under the heading "Sections" are of particular interest to younger members of the Institute.

Section and Branch Statistics

Data on the Sections and Branches are given in table I.

Table I—Section and Branch Statistics

	For Fiscal Year Ending			
	April 30, 1929	April 30, 1931	April 30, 1933	April 30, 1935
Sections				
Number of Sections	54	59	60	61
Number of Section meetings held	460	491	498	521
Total attendance	73,254	108,523	73,806	73,381
Branches				
Number of Branches	100	109	111	117
Number of Branch meetings held	940	1,137	1,026	986
Total attendance	47,408	51,807	59,439	36,629

Technical Program Committee

The principal work of the technical program committee throughout the year has consisted of providing technical papers for the national conventions and the reviewing of papers to determine their suitability for presentation and publication. In addition, the committee has supplied some papers for the District meetings and it has assisted the committee on award of Institute prizes by grading each paper when initially reviewed.

In the arranging of technical programs the committee has endeavored to meet the technical requirements of the membership in so far as possible. Guided by an analysis of the character of material previously presented, 2 symposiums on electronics were held at the last winter convention, as well as a session on illumination. Sessions devoted entirely to the subject of electronics have not been held heretofore and the subject of illumination had not been on a convention program for a number of years.

The committee has raised the standard of papers as a result of grading them when initially reviewed for acceptance. This practice, together with the need to keep within the annual budget during these times, has led the reviewers to be more selective in their acceptance of papers as evidenced by a greater number of rejections. In addition, a number of papers were returned to the authors for revision and condensation to eliminate nonessential material. The average number of pages per paper has been reduced. In this way, the committee has continued to keep within the annual budget of 750 pages for the 3 national conventions, and permit the greatest number of authors to express their views. Progress has also been made toward reducing the time required for review, authors' revisions, and the handling of papers.

The foregoing results can best be seen from a comparison of papers for the past year with those of 5 years ago for the year 1929–30, as presented in table II. The average page length per paper has been reduced from 8.1 to 6.1. During the past year 28 per cent of the papers considered were not accepted, as compared with only 11 per cent 5 years ago. For the summer convention, the average number of days per paper required for review, revision, and handling has been reduced from 61.9 to 30.6. For the winter convention, this time has been reduced from 67 days to 49.2 days, while the Pacific Coast convention and the District meetings show an increase in the time required for review. However, the papers for the winter and summer conventions comprise more than half of the total number of papers for the year. The time required for review, based upon data taken over the entire year, remained about the same due to the long period of time required for authors' revisions of some District meeting papers, several of which were not published until after the meetings.

The committee has co-operated with the publication committee in obtaining papers further in advance of conventions and scheduling them for publication in intervals so that the sizes of the issues of ELECTRICAL ENGINEERING could be kept uniform. A production control board has been installed for this purpose. On this board each paper is posted from the time first received and it is possible to follow the paper through the various steps of review and revision until published. The board is very useful in indicating in which steps the material is not moving smoothly, and it is also helpful in indicating for a period of several months in advance whether or not there will be sufficient material for the succeeding issues.

The committee also has continued its policy of reviewing the discussions and a number of them have been returned to discussers for revision or cancellation. Broader discussion of some papers has been obtained by their re-presentation on later programs in other sections of the country. Thus the material for this department of publication has been kept on a high standard.

The committee has also revised and approved the "Definitions of Scopes of Technical Committees." These definitions, based upon agreements as to the division of work among the technical committees, will bring about a more harmonious and efficient functioning of committee work, and they will be particularly helpful to the incoming chairmen.

Acknowledgment is extended to the members of the committee, the technical committees, reviewers, and members of the headquarters staff for their co-operation, which has brought about the smooth functioning of committee work.

Table II—Comparison of Papers for Past Year With Those for the Year 1929–30

Based Upon Papers Reviewed by the Technical Program Committee

April 30, 1929 to April 30, 1930	No. Papers	Total No. Pages	Avg. Page Length Per Paper	Avg. No. Days Req. for Review, Revision, and Handling[1]	Avg. No. Days Req. for Publication in Pamphlet Copies for Use at Meetings
National Conventions					
Swampscott, June 24–28	†44	344	7¾	61.9	40.0
Santa Monica, Sept. 3–6	19	143	7½	27.7	28.2
New York, Jan. 27–31	50	433	8½	67.0	39.2
District Meetings					
Dallas, May 7–9	13	79	6	26.4	22.4
Chicago, Dec. 2–4	18	169	9¼	38.7	37.7
Published in JOURNAL only	6	54		198.2	148.0
Yearly averages	132	1222	8.2	58.4	40.8
Withdrawn and rejected (11 per cent)					

April 30, 1934 to April 30, 1935	No. Papers	Total No. Pages	Avg. Page Length Per Paper	Avg. No. Days Req. for Review, Revision, and Handling[1]	Avg. No. Days Req. for Publication in ELEC. ENGG. for General Circulation
National Conventions					
Hot Springs, Va., June 25–29	30	190½	6¼	30.6	46.8
Salt Lake City, Sept. 3–7	*25	149¼	7½	48.0	59.8
New York, Jan. 22–25	53	345	6½	49.2	56.6
District Meetings					
Worcester, Mass., May 16–18	12	58	4¾	113.0	81.5
Oklahoma City, April 24–26	**7	22¼	4½	127.8	43.0
Published in ELEC. ENGG. only	22	100		78.0	160.4
Yearly averages	142	865	6.1	58.1	72.3
Withdrawn and rejected (28 per cent)					

1. Includes review by committees, revision by authors, and other handling previous to release for publication.
† Includes 18 technical committee reports.
* Includes 5 papers re-presented; 4 from winter convention program and 1 from Worcester meeting.
** Includes 2 papers re-presented from winter convention programs.
(These 3 items not included in vertical column totals.)

Publication Committee

The calendar year 1934 was the peak year in the history of the Institute's publications, first, in the total amount of material published, and, second, in the fact that all this material was distributed to the entire membership of the Institute.

Following the procedure embraced in the unified publication program adopted by the board of directors in August 1933, the Institute's official monthly organ, Electrical Engineering, in its enlarged form now carries to the Institute's membership the full text of all recommended A.I.E.E. papers and the full text of all accepted and recommended discussion of those papers. In addition to this formal technical content there has been retained, in response to widespread membership demand, a proportion of special articles and other features that have been highly popular with the membership since their adoption in January 1931. Further, news of Institute activities has been featured more strongly, and it is recommended that every effort be made to use this effective news distributing facility in order to keep the Institute membership better acquainted with the scope, character, and significance of Institute activities and operating problems.

Beginning with volume 53 (1934) the Transactions has, for reasons of economy and equity in the distribution of the costs involved, been changed to an annual volume in accordance with the provisions of the unified publication program. Inasmuch as the monthly issues of Electrical Engineering convey all material directly and promptly to the membership, the annual Transactions is issued as a supplementary service to those who wish a permanently bound volume for library or reference purposes. Because of the inclusion of an extra quota of 125 pages embracing 19 technical papers to close the gap between the annual volume and the last quarterly Transactions, and because of the 199 pages embracing the special content of the May 1934 fiftieth anniversary issue of Electrical Engineering, the 1934 annual volume was appreciably larger than the average to be expected.

In general, the new publication program may be said to be safely past the principal difficulties incident to the major transition, although of course several minor operating problems now remain to be worked out. The plan has been enthusiastically accepted by the membership in general, and the expected substantial improvement in publication service and reduction in publication costs have become realities.

Standards Committee

As the practice of holding 4 meetings of the standards committee per year has been found satisfactory and the cause of but little delay in the carrying on of routine matters, it was continued during the past year with meetings in May and October 1934 and January and April 1935.

Most of the time of the committee this year was devoted to the consideration of revisions of existing A.I.E.E. and approved American standards as submitted by the technical committees of the Institute, notably the electrical machinery, instruments and measurements, and protective devices committees. These projects thus received and forwarded to the American Standards Association were as follows: air switches, instrument transformers, recording instruments, and lightning arresters. The third of the test code series, the "Test Code for Polyphase Induction Machines," was published in December 1934 and distributed for comment. The "Test Code for Transformers," the first to appear, was forwarded to the American Standards Association and is now before the sectional committee on transformers.

Changes brought about by present industrial conditions necessitated the realignment of the Institute representatives on several sectional committees. In support of its belief in the effectiveness of single sponsorship for sectional committees, the Institute released its joint sponsorship of the sectional committee on radio. This committee will now be under the sole direction of the Institute of Radio Engineers.

Among the many miscellaneous questions coming up for attention were 2 of particular interest, as follows: a suggestion that there be a reclassification of insulation materials, the careful consideration of which resulted in a reaffirming of the present setup; the other question was essentially one of clarification and resulted in the decision that the phrase "limit of temperature rise" should henceforth be "limit of observable temperature rise."

A matter of perhaps great importance chiefly as indicative of the growth of the American Standards Association, but which was called to the attention of the standards committee because of its possible bearing on the work of the electrical standards committee of A.S.A. was the plan now being considered by that organization, which may eventually result in the work of the standards council in fields other than electrical and of the general nature of that now handled by the Electrical Standards Council being delegated to similarly organized committees. The standards committee expressed the informal opinion that the proposal would seem to be a step toward more effective operation of standards council.

U.S. National Committee of the I.E.C.

Meetings of 6 of the advisory committees of the International Electrotechnical Commission were held in Prague in October 1934. Progress was made on the technical work and foundations were laid for the plenary meetings which will be held in The Hague and Brussels, June 18–27, 1935.

Following is a brief résumé of the work accomplished by the advisory committees which met at Prague:

Advisory Committee Number 2, on the Rating of Electrical Machinery. This committee concerned itself with the proposed revision of I.E.C. publication 34, "Rules for Electrical Machinery (including transformers)." The U.S. national committee has prepared its comments on the proposed revision which is now available. The committee also concerned itself with the preparation of an I.E.C. publication covering the measurement by sphere gaps of test voltage at power frequencies in dielectric tests. These comprise essentially the same provisions as A.I.E.E. Standards Number 4. While certain work which is being carried on in this country tends to indicate

errors in the proposed table, the U.S. committee has decided to agree to the publication of the I.E.C. rules and to move for an immediate revision upon the completion of the work on the subject in this country.

Advisory Committee Number 3, on Graphical Symbols. A comprehensive proposal for the standardization of graphical symbols for electric traction which was prepared by the Swiss national committee, the secretariat for this work, was considered in connection with the list of symbols recommended by the international union of railways. A single list of symbols was arrived at and it will be circulated to the national committees for approval before publication as an I.E.C. standard.

Advisory Committee Number 6, on Lamp Bases and Sockets. Recommendations prepared by the international committee of lamp manufacturers and independent experts were adopted with minor modifications. These cover dimensions essential to insure interchangeability of lamp bases and sockets of both the screw and bayonet type. The recommendations cover bases and sockets of both the American and European types. The committee expects to continue the work on gauging.

Advisory Committee Number 8, on Standard Voltages and Currents and High Voltage Insulators. This committee prepared lists of I.E.C. nominal voltages and a series of standard current ratings for electrical apparatus which are now under consideration by the U.S. national committee. Tentative agreement also was reached on a draft of international specifications for the testing of overhead line insulators, and the draft specification is receiving consideration by the U.S. national committee.

Advisory Committee Number 17, on Switchgear. The work of this committee comprises the most important subject before the I.E.C. at the present time. The meeting considered a complete specification for the rating and performance of circuit breakers submitted by the British, and a committee of experts was appointed to meet monthly to prepare recommendations for consideration at the plenary meetings. The U.S. national committee is represented on this committee of experts.

Advisory Committee Number 20, on Electric Cables. Preliminary work was done by this committee looking to the establishment of an I.E.C. specification covering the testing of cables.

At a meeting of the committee of action it was decided to reconstitute the former advisory committee on rules for electrical installation on ships, and to establish new advisory committees covering electronic devices and the rating of rectifiers, and to take the initiative in convening an international conference to standardize, for international purposes, acoustical terms and definitions.

The U.S. National committee at its January meeting elected Dr. A. E. Kennelly, past president A.I.E.E. and professor emeritus of electrical engineering at Harvard University, as its honorary president. Dr. Kennelly has served the U.S. National committee and the I.E.C. with distinction on nomenclature, electric and magnetic magnitudes and units, rating of electrical machinery, and on many other important subjects.

The U.S. national committee has made careful preparations for the plenary meetings to be held at The Hague and Brussels, and at the time of the writing of this report it appears that American electrical industries will be represented by one of the largest and best technically qualified delegations which have been sent abroad in several years.

Co-ordination Committee

The committee followed the established practice of requesting District and Section officers to submit by January 1 applications for the authorization of any national conventions and District meetings desired in their respective Districts during the calendar year 1936. A schedule of 2 national conventions and 2 District meetings was recommended by the committee.

The 1934 annual report of the committee on research, containing recommendations that research be given more prominence in Institute affairs and that this committee be made a general committee, had been referred by the board of directors to the committee on co-ordination of Institute activities. The committee recommended that no change be made in the status of the committee on research, as its activities are not restricted in any manner by the present arrangement, which offers some advantage in unity and in helpfulness to other technical committees.

Certain revisions in the rules governing the award of prizes for papers submitted by the committee on award of Institute prizes were recommended to the board of directors.

The board of directors approved the committee's recommendations on these 3 matters on January 21, 1935.

Committee on Constitution and By-Laws

During the year, the committee approved for presentation to the board of directors several proposed amendments to the by-laws of the Institute, and certain proposed amendments to the constitution, which had been recommended by a special committee, changing the dates in the Institute election procedure to permit the holding of the meeting of the national nominating committee during the winter convention, rather than early in December, thus providing for announcing the nomination of officers at a more appropriate time, and effecting other desirable results. Following approval by the board of directors, these proposed amendments to the constitution were submitted to a vote of the membership.

Committee on Legislation Affecting the Engineering Profession

The following matters were brought to the attention of this committee.

1. Effect of the federal securities bill on the responsibilities of the engineer.
2. Restrictions on the practice of consulting engineering, in the federal law on public utility holding companies.
3. Proposed licensing law in Cuba.
4. Proposed licensing law in Massachusetts.
5. New amendment to the licensing law of New York.

As the first 3 of these are matters which come in the category for which American Engineering Council was set up they were referred to that body and Secretary Feiker took the matters in charge.

The cases of state licensing were referred to the appropriate district executive committees.

No formal action was taken by the committee in any of the cases.

Committee on the Economic Status of the Engineer

The various matters which might otherwise have been acted upon by this committee during the year have seemed to lie definitely within the scopes of activities of American Engineering Council and Engineers' Council for Professional Development. As the chairman of the committee is one of the Institute's representatives upon each of these bodies, and chairman of the delegation to the former, the committee has not acted separately.

Committee on Safety Codes

No meetings of this committee have been called because no matters of importance have demanded consideration which could not be properly given by mail.

Two questions have been given the attention of the membership in this manner:

1. The request of the American Society of Safety Engineers' committee on co-operating with other engineering societies was discussed and, as a result, the Institute committee has recommended that A.I.E.E. co-operate in this movement. It is the purpose of this movement to bring about a closer co-ordination of the efforts of the several professional engineering societies in safety matters, for the benefit of all. The chairman of the committee on safety codes has been designated as the point of contact for effecting such co-operation.

2. The members of the committee have commented on the merits of the "bare neutral" system of interior wiring for the benefit of the chairman in representing A.I.E.E. on the electrical committee of the National Fire Protection Association.

At the meeting of the electrical committee in New York, March 19 to 22, many revisions were voted into the National Electric Code. A.I.E.E. men, several of them members of the committee on safety codes, were active participants in these revisions. It was decided to give the N.E.C. a complete editorial revision to be reported for action in the 1936 meeting. The previous chairman of the committee on safety codes, because of his neutral status, was made chairman of a special technical committee on bare neutral for interior wiring systems in 1932. His report was presented, and his committee was discharged.

The chairman also represents A.I.E.E. on the committee on low voltage hazards of the A.S.S.E., Engineering Section, National Safety Council. This assignment has required no action during the year.

Similarly, the chairman represents A.I.E.E. on the National Fire Waste Council, United States Chamber of Commerce, and attended the annual meeting held in Washington, D. C., on March 29. No matters of vital concern to the committee were discussed in this meeting.

Technical Committees

The technical committees, under the leadership of the technical program committee, have continued their efforts to clarify the definitions of scopes of their activities, in order to make definite provisions for effectively covering all the desired ranges of subjects and to eliminate overlapping among the committees.

They have continued their usual activities in the stimulation of the preparation and presentation of desirable papers in their respective fields and in the review of technical papers submitted.

Membership Committee

The membership committee continued its work with a complete national, District, and Section organization throughout the entire year even including the summer months. The threefold aim of the activities of this group has been to obtain applications for membership, to bring Students into Associate membership, and to urge and help members to reinstatement. In this work it has been aided greatly by the entire membership in their response to appeals to send to the committee the names of those who, they felt, should be invited to join the Institute. This method has been found to be fruitful of results and it is being continued. Membership messages have been carried in all issues of Electrical Engineering and, in addition, the Section organizations have contacted their members in many different ways. Monthly reports to the Section membership committees have served to keep the results in tangible form.

The committee had hoped to be able to report a net increase in members but this has not yet been accomplished. As is seen from table III, there is a reduction in membership from last year. However, there are other factors which give greater promise to the future. From table IV it will be seen that the number of applications received from enrolled Students and from all others has increased and from

Table III—Membership Statistics for the Fiscal Year Ending April 30, 1935

	Honorary	Fellow	Member	Six-Year Associate	Associate	Total
Membership on April 30, 1934	15	714	3694	6149	4659	15,231
Additions						
Transferred		17	180	510		
New members qualified		5	96	12	953	
Former members reinstated		2	26	35	25	
Total	15	738	3996	6706	5637	17,092
Deductions						
Died	3	18	29	32	9	
Resigned		6	49	174	88	
Transferred			13	152	542	
Dropped		23	195	731	775	
Membership on April 30, 1935	12	691	3710	5617	4223	14,253

Table IV—Number of Applications Received From Enrolled Students and From All Others

Year Ending	From Students	From All Others	Total
April 30, 1935	575	715	1,290
April 30, 1934	467	496	963
April 30, 1933	674	305	979
April 30, 1932	779	612	1,391
April 30, 1931	533	964	1,497

Table V—Number of Enrolled Students

April 30, 1935	3806 (1983)
April 30, 1934	3186 (1548)
April 30, 1933	3260 (1494)
April 30, 1932	3700 (1624)
April 30, 1931	3813 (2218)

(Following the number of Students reported for April 30th of each year is indicated within parentheses the number of new applications received during that year; the difference between this number and the reported total, of course, reflects the number of renewals of Student enrollment for the corresponding period.)

Table VI—Number of Members in Section Territory Reinstated

August 1, 1934, to April 30, 1935	697
Year beginning August 1, 1933	741
Year beginning August 1, 1932	277
Year beginning August 1, 1931	327
Year beginning August 1, 1930	375

Table VII—Membership of the Institute, April 30, 1935

Of the 14,253 membership reported for April 30, 1935, 11,496 are fully paid to April 30, 1935. The balance of 2,757 are divided into the following groups:

1. Members owing dues to April 30, 1934.	
Total number of members who have not acted upon resolution of board of directors adopted in January 1935 providing an extension of time for payment of these dues (including 437 members of 6 years' standing or longer who were entitled, upon application, to dues cancellation if unemployed during corresponding fiscal year)	903
Total number of members who obtained dues cancellation to April 30, 1934, because of unemployment, but who have not yet renewed active membership on pro rata basis for current year as provided in resolution of board of directors adopted in January 1935	18
	921
2. Members owing dues to April 30, 1935	1,836

(During the period May 1 to 20, 1935, 312 members have paid dues to April 30, 1935, reducing the total to 1,524.)

Table VIII—Memberships Fully Paid

	Membership as of April 30	Number of Members Fully Paid as of April 30	Per Cent Fully Paid
1935	14,253	11,496	80.6
1934	15,230	11,028	72.4
1927 (year of maximum membership)	18,344	16,247	88.5

table V it will be seen that the number of enrolled Students has increased. Table VI shows that the number of members in Section territory reinstated has increased.

Table VII shows that the number of members being carried whose dues are not fully paid is 2,757, whereas this figure was 4,202 as of April 30, 1934. This represents a decided improvement. Table VIII shows the improved condition as regards membership fully paid.

It is not possible in a short space to picture adequately the great amount of work which the Section membership committee chairmen and their committees continually contribute to the membership activities of the Institute. The fact that applications have been received during the past year from every Section of the Institute, as was also the case last year, shows the universality of the work and the completeness of the extent of the activities. It is due to the work of these groups combined with the efficient work of the headquarters staff in its manifold forms that the membership figures are good.

Deaths

The following deaths have occurred during the year:

Honorary Members: George A. Hamilton, Michael I. Pupin, Frank Julian Sprague.

Fellows: Charles G. Adsit, W. Rawson Collier, Harry A. Currie, George A. Damon, Roy W. Gray, Elwood Grissinger, George H. Harries, Edward M. Hewlett, Edward D. Mathey, Natalis Mazen, William McLellan, Samuel G. McMeen, Charles W. Parkhurst, Leslie L. Perry, Dana Pierce, Calvin W. Rice, Harris J. Ryan, Thomas A. Watson.

Members: William C. Adams, Ray M. Allen, George W. Atkinson, John C. Barclay, C. O. C. Billberg, George F. Brown, Edgar A. Cerf, Jr., Floyd E. Dellinger, Leonard P. Dickinson, John E. Donoghue, Fred D. Emory, G. L. Evans, George S. Gardner, Christopher M. Goddard, Hermann C. Henrici, Rudolph M. Hunter, James M. Kent, Ralph R. Laxton, George M. McCarty, James Milne, Guy K. Mitchell, Warren Partridge, Frederick G. Proutt, Paul W. Ripple, Martin L. Roper, William M. Scott, Paul B. Seiden, W. C. Spruance, Charles H. Wilson.

Associates: William E. Ahrens, Donald C. Allison, Herbert A. Barre, Wilfred T. Birdsall, Leon B. Boulavin, Alonzo B. Bradley, Carleton M. Brown, Will G. Cole, George E. Dania, Harry H. Danshoe, Arthur W. Dawson, Thomas J. Drury, Edward M. Duvoisin, Herschel H. Edwards, Burch Foraker, Charles E. Hendricks, Foster D. Keese, Alfred W. Kiddle, Claude King, Charles K. Kneale, Mitchell A. Kreindler, W. Roy McCanne, Fred W. McKown, John A. McManus, Donald P. McNitt, Kikutaro Nogami, Philander Norton, Frank O'Ryan, Henry E. Phelps, Joseph C. Potts, Charles W. Price, Edgar F. Price, Kenneth A. Reed, R. Seshasayee, James F. Sinclair, Torsten F. Son Holmgren, Jerome G. Van Zandt, Harry Von Turffs, Ernest White, Richard L. Wilson, Walter Wood.

Board of Examiners

The board of examiners held 11 meetings during the past year, averaging about $2^1/_4$ hours each, and considered 3,176 cases, divided as shown in table IX.

Table IX—Applications for Admission and Transfer

Applications for Admission		
Recommended for grade of Associate	773	
Re-elected to the grade of Associate	57	
Not recommended	8	838
Recommended for grade of Member	103	
Re-elected to the grade of Member	10	
Not recommended	35	148
Recommended for grade of Fellow	3	
Re-elected to the grade of Fellow	2	
Not recommended	1	6
Applications for Transfer		
Recommended for grade of Member	199	
Not recommended	23	222
Recommended for grade of Fellow	19	
Not recommended	2	21
Students		
Recommended for enrollment as Students		1,941
Total		3,176

Institute Prizes

Four national prizes and 11 District prizes for papers presented in 1934 were awarded to authors. The national prizes were presented at the summer

convention at Hot Springs, and most of the District prizes were presented at various meetings in the respective Districts. The awards were announced in 1934 issues of ELECTRICAL ENGINEERING for June (page 1026), July (pages 1234–5), and September (pages 1327–8).

COMMITTEE ON AWARD OF COLUMBIA UNIVERSITY SCHOLARSHIPS

The committee selected for the award of the scholarship placed at the disposal of the Institute, for the class entering upon graduate study in electrical engineering at Columbia University in the fall of 1934, Robert W. Marshall of station *F*, route 4, Minneapolis, Minn. As usual the availability of these scholarships was announced in the February issue of ELECTRICAL ENGINEERING and in a circular letter to the Counselors of all Student Branches of the Institute.

EDISON MEDAL

The Edison Medal, which is awarded by a committee composed of 24 members of the Institute, was, for 1934, awarded to Dr. Willis R. Whitney "for his contributions to electrical science, his pioneer inventions, and his inspiring leadership in research," and was presented on January 23, 1935, during the winter convention. The medal may be awarded annually "for meritorious achievement in electrical science, electrical engineering, or the electrical arts."

JOHN FRITZ MEDAL

The John Fritz Medal board of award, composed of representatives of the national societies of civil, mining, mechanical, and electrical engineers, awarded the thirty-first medal (for 1935) to Dr. Frank J. Sprague, honorary member and past-president of the Institute, "for distinguished service as inventor and engineer through the application and control of electric power in transportation systems." Dr. Sprague's death occurred on October 25, 1934, only a few days after he had received notification of the award. The medal was presented to his son Robert C. Sprague on January 23, 1935, during the winter convention.

LAMME MEDAL

The Lamme Medal committee awarded the medal for 1934 to Henry E. Warren "for outstanding contributions to the development of electric clocks and means for controlling central station frequencies." Arrangements are being made for the presentation of the medal at the annual summer convention, at Ithaca, N. Y., June 24–28, 1935. The medal may be awarded annually to a member of the A.I.E.E. "who has shown meritorious achievement in the development of electrical apparatus or machinery."

WASHINGTON AWARD

The Washington Award for 1935 was bestowed upon Dr. Ambrose Swasey, honorary member of the Institute, "for his distinguished contributions as a builder of instruments, institutions, and men," and was presented to him on February 20, 1935. This award may be made annually to an engineer by the commission of award composed of 9 representatives of the Western Society of Engineers and 2 each of the A.S.C.E., A.I.M.E., A.S.M.E., and A.I.E.E.

ALFRED NOBLE PRIZE

This prize, established in 1929, consists of a certificate and a cash award of $500 from the income from a fund contributed by engineers and others to perpetuate the name and achievements of Alfred Noble, past-president of the A.S.C.E. and of the Western Society of Engineers. It is made to a member of any of the co-operating societies, A.S.C.E., A.I.M.E., A.S.M.E., A.I.E.E., or W.S.E., for a technical paper of particular merit accepted by the publication committee of any of these societies, provided the author, at the time of such acceptance, is not over 30 years of age. No award was made in 1934.

IWADARE FOUNDATION COMMITTEE

The third lecturer to visit Japan was Dr. Irving Langmuir of the General Electric Company. Doctor Langmuir spent several weeks toward the latter part of 1934 in Japan and addressed many audiences at a number of the leading universities.

The sixth Iwadare Fellow to visit the United States was Mr. Y. Takahashi of the Meidensha Electric Works, Tokyo, and a part-time lecturer at the Imperial University. His visit began in April of last year.

EMPLOYMENT SERVICE

The Institute co-operates with the national societies of civil, mining, and mechanical engineers in operation of the Engineering Societies Employment Service with its main office in the Engineering Societies Building, New York. Offices are operated in Chicago and San Francisco also. In addition to the societies named, others co-operate in certain of the offices as follows: New York—Society of Naval Architects and Marine Engineers; Chicago—Western Society of Engineers; San Francisco—California Section of the American Chemical Society; and the Engineers' Club of San Francisco.

The New York office has co-operated closely with the Professional Engineers Committee on Unemployment which was organized in the fall of 1931 by the local Sections of the A.S.C.E., A.I.M.E., A.S.M.E., and A.I.E.E.

The service is supported by the joint contributions of the societies and their individual members who are benefited. As in the past, it consists principally in acting as a medium for bringing together the employer and the employee. In addition to the publication of the employment service announcements monthly in ELECTRICAL ENGINEERING, weekly subscription bulletins are issued for those seeking positions.

An analysis of this employment service is given in table X.

Table X—Analysis of Employment Service

Month	Men Registered				Men Placed			
	New York	Chicago	San Francisco	Total	New York	Chicago	San Francisco	Total
1934								
May	86	71	55	212	46	19	16	81
June	145	76	66	287	50	9	8	67
July	129	47	46	222	51	18	13	82
August	85	47	45	177	61	22	17	100
September	99	28	34	161	51	12	13	76
October	113	41	58	212	49	40	16	105
November	90	38	37	165	41	23	10	74
December	72	41	31	144	42	12	15	69
1935								
January	102	61	57	220	50	15	17	82
February	101	39	45	185	60	16	13	89
March	79	45	49	173	62	20	13	95
April	109	39	56	204	64	28	12	104
Total	1,210	573	579	2,362	627	234	163	1,024

American Engineering Council

During the past year, American Engineering Council has continued its activity in the wide range of affairs which lie within its objects: "to further the public welfare wherever technical and engineering knowledge and experience are involved, and to consider and act upon matters of common concern to the engineering and allied technical professions," and within the interests of the many national, state, and local engineering societies upon its membership list.

Some of the principal actions taken by the Council at its annual meeting held January 10–12, 1935, provide for:

1. New membership plan under which local societies may pay nominal dues on a flat rate basis.

While formal promotion of the new membership plan has not yet been actively started, Council has already received applications for membership under the new plan from the following organizations:

Engineering Societies of New England
Michigan Engineering Society
Cleveland Engineering Society
Providence Engineering Society
Arkansas Engineers' Club
Engineers' Club of Philadelphia
Engineers' Club of St. Louis
Louisiana Engineering Society
Florida Engineering Society

2. Division of the public affairs committee into subcommittees under the chairmanship of members of the main committee who will co-operate with similar committees of the engineering societies.

3. Organization of a public affairs committee in each state.

4. Continued support of the national mapping program.

5. Efforts to have the facts concerning rural electrification work, scattered among several departments, pooled under the bureau of agricultural engineering, with data already collected by engineering groups throughout the country.

6. Continuance of the holding of a conference of secretaries of engineering societies from time to time.

7. Increase in Council's budget of 1/3 over that of 1934, thus enabling it to render more effective service.

Much of the annual meeting was devoted to symposiums on parts of the federal program connected with construction, planning, and other features involving engineering, with government officials presenting information and leading the discussions. Thus, the members of the governing bodies of the Council received much information which will be helpful in their further deliberations on these subjects.

A conference of secretaries of approximately 40 national, state, and local engineering societies was held in connection with the meeting, and many problems common to engineering societies of various types were discussed. A committee was appointed to study the interrelations of activities of national, state, and local engineering organizations.

At the request of the Council, and with the co-operation of many of the engineering societies, the U.S. Department of Labor is making a survey of the engineering profession, using a list of more than 170,000 engineers, for the purpose of ascertaining facts regarding engineering employment during the past several years, particularly with respect to education, types of work, and compensation.

More detailed information regarding the work of the Council in its broad range of activities may be found from month to month in Electrical Engineering.

United Engineering Trustees, Inc.

During 1934, this organization, as an agency of the founder societies, made many improvements in the facilities of the Engineering Societies Building, changed the arrangements for fire insurance to make reductions in cost, revised the by-laws, and performed other duties necessary to maintain the building and administer the funds in its custody, including those of its departments, The Engineering Foundation and the Engineering Societies Library.

Dr. Alfred D. Flinn resigned as secretary, and John Arms, who had previously been appointed general manager, was elected secretary in addition. Dr. Flinn continues as director of The Engineering Foundation.

The United Engineering Trustees, Inc., and the secretaries of the founder societies made plans for a joint dinner meeting of the officers and boards of the societies and of their joint organizations held on May 20, 1935, for the purpose of establishing a better understanding among these individuals of the many important activities conducted by these jointly operated agencies.

Abstracts of the annual report of the United Engineering Trustees, Inc., were published in the April 1935 issue of Electrical Engineering, page 458.

Engineering Foundation

This department of the United Engineering Trustees, Inc., supplied financial support, during 1934, for many research projects sponsored by the founder societies, notably the following: A.S.C.E.—concrete and reinforced concrete arches, earths and foundations, and plastic properties of concrete; A.I.M.E.—critical review of world's literature on alloy irons and alloy steels since 1890, and barodynamic research; A.S.M.E.—effects of temperature upon properties of

metals, cutting of metals, thermal properties of steam, mechanical springs, riveted joints, and wire rope; A.I.E.E.—welding with pure iron electrodes.

The Foundation also assisted the Engineers' Council for Professional Development, the Personnel Research Federation, and an investigation of the Engineering Index.

The Foundation has authorized the formation of a welding research committee, under the sponsorship of the American Welding Society and the Institute, to make a critical review of welding literature and later to develop a comprehensive program of research.

The Foundation's twentieth anniversary was celebrated at a dinner meeting on October 18, 1934, with Dr. Ambrose Swasey, founder, present as the guest of honor.

An abstract of the annual report of The Engineering Foundation was published in the April 1935 issue of ELECTRICAL ENGINEERING, pages 458–9.

Engineering Societies Library

The Engineering Societies Library, which was formed by combining the separate libraries of the 4 national societies of civil, mining and metallurgical, mechanical, and electrical engineers, and the preparation of a composite card catalog, has been expanded as a single engineering library, which probably constitutes the best collection of this type of literature in the country. With its 145,000 volumes, about 1,200 periodicals in many languages received regularly, and its staff thoroughly experienced in rendering all library services required by engineers, by mail, as well as in the library, it has continued, despite drastic reductions in its budget, to afford highly appreciated assistance to increasing numbers of members of the co-operating societies. Special, services rendered include: photoprints, abstracts, translations, bibliographies, searches, book loans by mail, etc.

A more comprehensive statement regarding the library, prepared by Professor W. I. Slichter, national treasurer of the Institute, and chairman of the library board, appeared in the January 1935 issue of ELECTRICAL ENGINEERING, pages 130–31.

Engineers' Council for Professional Development

This council, which was formally organized in 1932 for the enhancement of the professional status of the engineer, includes 3 representatives of each of the 7 participating organizations: the national societies of chemical, civil, electrical, mechanical, and mining and metallurgical engineers, the Society for the Promotion of Engineering Education, and the National Council of State Boards of Engineering Examiners.

The principal activities of the Council include the guidance of young individuals thinking of entering the engineering field, the accrediting of engineering schools, encouragement and assistance to individuals continuing their engineering and cultural training during several years after graduation, and the establishment of suitable standards for indicating the attainment of the status of an engineer.

Detailed information regarding the recommendations submitted by E.C.P.D. to the participating organizations and other features of its activities were published in ELECTRICAL ENGINEERING for February 1935, page 249, March, page 343, and April, page 452.

Representatives

The Institute has continued its representation upon many joint committees and national bodies, with which it co-operates in a wide range of activities of interest and importance to engineers and others.

Finance Committee

The committee, as usual, recommended a detailed budget to the board of directors, passed upon the expenditures for various purposes, made recommendations regarding delinquent members, and performed the other duties prescribed for it in the constitution and by-laws.

Haskins and Sells, certified public accountants, have audited the books, and their report follows.

Respectfully submitted for the board of directors.

H. H. HENLINE
National Secretary

May 20, 1935

HASKINS & SELLS
CERTIFIED PUBLIC ACCOUNTANTS

22 EAST 40TH STREET
NEW YORK

May 15, 1935.

American Institute of Electrical Engineers,
33 West 39th Street,
New York.

Dear Sirs:

We have made an examination of your statement of financial condition as of April 30, 1935, and of your recorded cash receipts and disbursements for the year ended that date. In connection therewith we examined or tested accounting records of your society and other supporting evidence in relation to the balance sheet and cash receipts and disbursements, but we did not make a detailed audit of the transactions. We present the following financial statements:

Balance Sheet, April 30, 1935 (Exhibit A).
Property and Restricted Funds—Securities, Cash, and Accrued Interest Receivable (Schedule 1).

Statement of Recorded Cash Receipts and Disbursements of General Fund for the Year Ended April 30, 1935 (Exhibit B).

Statement of Recorded Cash Receipts and Disbursements of Property and Restricted Funds for the Year Ended April 30, 1935 (Exhibit C).

In accordance with the terms of our engagement the members and other debtors were not requested to confirm to us the amounts receivable from them at April 30, 1935, and in accordance with the usual practice of the Society, no provision has been made for dues which may prove to be uncollectible.

In our opinion, subject to the foregoing, Exhibit A fairly presents your financial condition at April 30, 1935, and Exhibits B and C set forth your recorded cash receipts and your disbursements of the funds as indicated during the year ended that date.

Yours truly,

HASKINS AND SELLS

Exhibit A

Balance Sheet, April 30, 1935

ASSETS

Property Fund Investments:		
One-fourth interest in real estate and other assets of United Engineering Trustees, Inc., exclusive of Trust Funds	$496,948.48	
Equipment:		
Library—Volumes and fixtures	37,296.37	
Office furniture and fixtures (less reserve for depreciation, $22,961.46)	10,043.45	
Works of art, etc.	3,001.35	
Securities—at cost, and cash—Schedule 1	10,065.00	
Total property fund investments		$557,354.65
Restricted Fund Investments—Schedule 1:		
Securities—At cost (less reserve for bonds of doubtful value)	$167,179.02	
Cash	7,267.17	
Accrued interest receivable	223.33	
Total restricted fund investments		174 669.52
Current and Working Assets:		
Cash	$ 54,815.62	
Accounts receivable:		
Members—For dues	23,014.04	
Advertisers	111.00	
Miscellaneous	2,982.01	
Accrued interest on investments	1,840.36	
Inventories:		
QUARTERLY TRANSACTIONS, etc.	2,311.50	
Text and cover paper	1,821.03	
Badges	703.03	
Total current and working assets		87,598.59
Total		$819,622.76

LIABILITIES

Property Fund Reserve		$557,354.65
Restricted Fund Reserves:		
Reserve Capital Fund	$154,528.25	
Life Membership Fund	9,659.60	
International Electrical Congress of St. Louis Library Fund	4,801.12	
Lamme Medal Fund	4,648.13	
Mailloux Fund	1,032.42	
Total restricted fund reserves		174,669.52
Current Liabilities:		
Accounts payable	$ 4,755.06	
Dues received in advance	3,319.20	
Entrance fees and dues advanced by applicants for membership	621.00	
Subscriptions for QUARTERLY TRANSACTIONS received in advance	48.00	
Total current liabilities		8,743.26
Surplus		78,855.33
Total		$819,622.76

Exhibit A, Schedule 1

Property and Restricted Funds—Securities, Cash, and Accrued Interest Receivable, April 30, 1935

			Restricted Funds					
	Number of Shares of Stock or Face Value of Bonds	Property Fund (Equipment Replacements)	Reserve Capital Fund	Life Membership Fund	International Electrical Congress of St. Louis Library Fund	Lamme Medal Fund	Mailloux Fund	Total
SECURITIES:								
Railroad Bonds:								
Baltimore & Ohio Railroad Company 6% refunding and general mortgage series C, due 1995	$12,000.00		$ 8,940.00			$4,330.00		$ 13,270.00
Central of Georgia Railway Company 5% consolidated mortgage, due 1945	3,000.00		1,477.50					1,477.50
Chicago, Burlington & Quincy Railroad Company 4%, due 1958	5,000.00			$4,868.75				4,868.75
Chicago, Burlington & Quincy Railroad Company 5% first and refunding mortgage series A, due 1971	1,000.00		1,010.00					1,010.00
Chicago & Erie Railroad Company 5% first mortgage, due 1982	1,000.00		1,105.00					1,105.00
Chicago & Northwestern Railway Company 6½%, due 1936	9,000.00		7,202.50					7,202.50
Chicago, Terre Haute & Southeastern Railway Company 5% first and refunding mortgage, due 1960	8,000.00		7,940.00					7,940.00
Florida East Coast Railway Company 5% first and refunding mortgage series A, due 1974 (certificates of deposit)	10,000.00		9,818.75					9,818.75
New York Central Railroad Company 5% refunding and improvement mortgage series C, due 2013	6,000.00		5,742.50					5,742.50
Pennsylvania Railroad Company 4½% general mortgage series A, due 1965	5,000.00		5,130.00					5,130.00
St. Louis-San Francisco Railway Company 5% prior lien mortgage series B, due 1950 (certificates of deposit)	6,000.00		5,497.50					5,497.50
Southern Railway Company 5% first consolidated mortgage, due 1994	1,000.00		980.00					980 00
Western Pacific Railroad Company 5% series A, due 1946	15,000.00		7,225.00					7,225.00
Total railroad bonds—(Forward)			$ 62,068.75	$4,868.75		$4,330.00		$ 71,267.50

Exhibit A, Schedule 1

Property and Restricted Funds—Securities, Cash, and Accrued Interest Receivable, April 30, 1935

	Number of Shares of Stock or Face Value of Bonds	Property Fund (Equipment Replacements)	Restricted Funds: Reserve Capital Fund	Restricted Funds: Life Membership Fund	Restricted Funds: International Electrical Congress of St. Louis Library Fund	Restricted Funds: Lamme Medal Fund	Restricted Funds: Mailloux Fund	Total
SECURITIES—Continued								
Total Railroad Bonds—(Forward)			$ 62,068.75	$4,868.75		$4,330.00		$ 71,267.50
Public Utility Bonds:								
Consolidated Gas Company of New York 5½% debentures, due 1945	$ 5,000.00		$ 5,187.50					$ 5,187.50
Duquesne Light Company 4½% first mortgage series A, due 1967	3,000.00		2,970.00					2,970.00
Hydro-Electric Power Commission of Ontario 3½%, due 1952	4,500.00		4,500.00					4,500.00
New York Telephone Company 4½%, due 1939	2,000.00				$ 878.75		$1,000.00	1,878.75
Pacific Gas & Electric Company 5½% first and refunding mortgage series C, due 1952	5,000.00		5,137.50					5,137.50
Philadelphia Company secured 5% series A, due 1967	10,000.00		10,000.00					10,000.00
Shawinigan Water & Power Company 4½% first mortgage and collateral trust sinking fund series A, due 1967	5,000.00		4,581.25					4,581.25
Texas Electric Service Company 5% first mortgage, due 1960	4,000.00		3,910.00					3,910.00
United Light & Power Company 5½% first lien and consolidated mortgage, due 1959	5,000.00		4,975.00					4,975.00
Total public utility bonds			$ 41,261.25		$ 878.75		$1,000.00	$ 43,140.00
Industrial Bonds:								
American Smelting & Refining Company 5% first mortage series A, due 1947	$ 9,000.00		$ 9,085.00					$ 9,085.00
Bethlehem Steel Company 5% purchase money and improvement mortgage sinking fund, due 1936	5,000.00		5,033.75					5,033.75
Cleveland Union Terminals Company 5% sinking fund series B, due 1973	4,000.00	$ 4,010.00						4,010.00
Fidelity Union Title and Mortgage Guaranty Company first mortgage certificates (on property 75–79 Prospect Street, East Orange, N. J.) 5½%, due 1933	14,663.00	977.53	13,685.47					14,663.00
International Match Corporation 5% convertible debentures, due 1941 (certificate of deposit)	3,000.00		2,880.00					2,880.00
New York Steam Corporation 6% first mortgage, due 1947	10,000.00		10,837.50					10,837.50
United States Rubber Company 5% first and refunding mortgage series A, due 1947	2,000.00		1,915.00					1,915.00
Western Electric Company 5% debentures, due 1944	10,000.00		9,818.75					9,818.75
Youngstown Sheet and Tube Company 5% first mortgage sinking fund series A, due 1978	10,000.00		10,137.50					10,137.50
Total industrial bonds		$ 4,987.53	$ 63,392.97					$ 68,380.50
Municipal Bonds:								
New York City 4½% corporate stock, due 1957	2,000.00				$2,204.05			$ 2,204.05
Capital Stocks:								
Commonwealth Edison Company	12 shares		$ 2,892.00					$ 2,892.00
Consolidated Gas Company of New York, $5.00 cumulative preferred	30 "	$ 3,060.00						3,060.00
Public Service Corporation of New Jersey, $5.00 preferred	30 "		2,958.75					2,958.75
United Gas Improvement Company, $5.00 preferred	30 "	1,995.00	997.50					2,992.50
Total capital stocks		$ 5,055.00	$ 6,848.25					$ 11,903.25
Total securities		$10,042.53	$173,571.22	$4,868.75	$3,082.80	$4,330.00	$1,000.00	$196,895.30
Less Reserve for Bonds of Doubtful Value:								
Central of Georgia Railway Company 5% consolidated mortgage, due 1945	$ 3,000.00		$ 1,477.50					$ 1,477.50
Florida East Coast Railway Company 5% first and refunding mortgage series A, due 1974	10,000.00		9,818.75					9,818.75
International Match Corporation 5% convertible debentures, due 1941	3,000.00		2,880.00					2,880.00
St. Louis-San Francisco Railway 5% prior lien mortgage series B, due 1950	6,000.00		5,497.50					5,497.50
Total reserve for bonds of doubtful value			$ 19,673.75					$ 19,673.75
Total securities, less reserve		$10,042.53	$153,897.47	$4,868.75	$3,082.80	$4,330.00	$1,000.00	$177,221.55
Cash		22.47	630.78	4,757.52	1,650.82	218.13	9.92	$ 7,289.64
Accrued Interest Receivable				33.33	67.50	100.00	22.50	$ 223.33
Total property fund securities and cash		$10,065.00						$ 10,065.00
Total restricted fund investments			$154,528.25	$9,659.60	$4,801.12	$4,648.13	$1,032.42	$174,669.52

Exhibit B

Statement of Recorded Cash Receipts and Disbursements of General Fund for the Year Ended April 30, 1935

Cash on Deposit, May 1, 1934, With the National City Bank of New York		$ 29,824.74
Receipts:		
Dues (including dues allocated to ELECTRICAL ENGINEERING subscriptions)	$166,734.06	
Advertising	25,038.10	
QUARTERLY TRANSACTIONS subscriptions	6,561.18	
ELECTRICAL ENGINEERING subscriptions	12,247.98	
Miscellaneous publications, etc.	6,268.15	
Students' fees	8,736.00	
Entrance fees	5,884.90	
Badges	1,287.15	
Transfer fees	965.00	
Interest on investments and bank balances	7,549.30	
Miscellaneous	50.53	
Total receipts		241,322.35
Total		$271,147.09
Disbursements:		
Publication expenses:		
ELECTRICAL ENGINEERING	$ 74,336.41	
QUARTERLY TRANSACTIONS	4,936.20	
Year book	2,192.59	
Miscellaneous	3,534.95	
Administrative expenses	40,717.61	
Institute Sections	25,464.32	
Institute meetings	10,286.11	
Institute branches	2,343.42	
American Engineering Council	8,000.00	
Forward	$171,811.61	$271,147.09

Total—(Forward)		$271,147.09
Disbursements—(Forward)	$171,811.61	
Traveling expenses:		
Board of Directors	4,301.78	
Branch Counselors	3,061.49	
Geographical districts:		
Executive Committees	604.89	
Vice Presidents	411.45	
National Nominating Committee	1,300.67	
President's Special Appropriation	124.69	
United Engineering Trustees, Inc.:		
Library assessment	8,192.15	
Building assessment	3,938.36	
Standards Committee	5,470.63	
Membership Committee	7,368.07	
Employment service	3,204.16	
American Standards Association	999.99	
Badges	1,291.64	
Retirement salary	2,700.00	
Finance Committee	400.00	
United States Committee of International Commission on Illumination	300.00	
Geographical district prize—Best branch paper	150.50	
John Fritz medal	164.88	
Technical Committees	205.44	
Headquarters Committee	80.73	
Code Committee	60.00	
Edison Medal Committee	188.34	
Total disbursements		216,331.47
Cash on Deposit, April 30, 1935, With the National City Bank of New York		$ 54,815.62

Exhibit C

Statement of Recorded Cash Receipts and Disbursements of Property and Restricted Funds for the Year Ended April 30, 1935

			Restricted Funds				
	Total	Property Fund (Equipment Replacements)	Reserve Capital Fund	Life Membership Fund	International Electrical Congress of St. Louis Library Fund	Lamme Medal Fund	Mailloux Fund
Cash on Deposit, May 1, 1934, With East River Savings Bank and National City Bank of New York	$7,870.99	$22.47	$630.78	$5,388.29	$1,560.99	$255.78	$12.68
Receipts:							
Interest on bonds	$ 620.00			$ 200.00	$ 135.00	$240.00	$45.00
Interest on bank balances	139.65			139.65			
Miscellaneous	1.10				1.10		
Total receipts	$ 760.75			$ 339.65	$ 136.10	$240.00	$45.00
Total	$8,631.74	$22.47	$630.78	$5,727.94	$1,697.09	$495.78	$57.68
Disbursements:							
Annual withdrawal authorized in by-laws	$ 970.42			$ 970.42			
Bronze and gold replicas of Lamme Medal	277.65					$277.65	
All other disbursements	94.03				$ 46.27		$47.76
Total disbursements	$1,342.10			$ 970.42	$ 46.27	$277.65	$47.76
Cash on Deposit, April 30, 1935, with East River Savings Bank and National City Bank of New York	$7,289.64	$22.47	$630.78	$4,757.52	$1,650.82	$218.13	$ 9.92

Discussions

Of A.I.E.E. Papers—as Recommended for Publication by Technical Committees

On this and the following 35 pages appear all remaining unpublished discussions of papers presented at the 1935 A.I.E.E. winter convention, New York, N. Y., January 22–25, and of a paper presented at the 1934 North Eastern District meeting, Worcester, Mass., May 16–18. Authors' closures where they have been submitted, will be found at the end of the discussion on their respective papers.

Members anywhere are encouraged to submit written discussion of any paper published in ELECTRICAL ENGINEERING, which discussion will be reviewed by the proper technical committee and considered for possible publication in a subsequent issue. Discussions of papers scheduled for presentation at an A.I.E.E. meeting or convention will be closed 2 weeks after presentation. Discussions should be (1) concise; (2) restricted to the subject of the paper or papers under consideration; and (3) typewritten and submitted in triplicate to C. S. Rich, secretary, technical program committee, A.I.E.E. headquarters, 33 West 39th Street, New York, N. Y.

The M.I.T. Power Factor Bridge and Oil Cell

Discussion and authors' closure of a paper by J. C. Balsbaugh, N. D. Kenney, and Alfred Herzenburg published in the March 1935 issue, pages 272–9, and presented for oral discussion at the selected subjects session of the North Eastern District meeting, Worcester, Mass., May 16, 1934. Other discussion of this paper was published in the May 1935 issue, page 559.

G. M. L. Sommerman (American Steel and Wire Co., Worcester, Mass.): If there is no effect of temperature lag of the various oil test cell parts, the loop power factor-temperature curves obtained on insulating oils as illustrated in figure 7 indicate a lag in one or more of the basic properties of such oils. Before discussing the phenomenon from this viewpoint, it seems pertinent to make some inquiries concerning the temperature variations which obtain within the measuring cell in these experiments.

From the construction of the cell, figure 4, it seems possible that some heat can be imparted to the cell envelope at its center as well as at the outside. If this is so, the temperature-radial distance curve would go through a minimum for the case of temperature increasing, and the temperature of the oil between the active electrodes would be lower than either thermocouple indicates. Likewise it would be higher on the cooling part of the cycle. Such a condition would, of course, explain the loop effect. Even if this condition existed, however, trustworthy results would have been obtained from the average of the thermocouple readings provided the couples were in intimate thermal contact with the active electrodes. A few words from the authors concerning these 2 points, the possibility of heat flow at the center of the cell envelope, and the nature of the contact of the thermocouples, would clear up this question.

Taking the loop effect as truly existing, the following explanation of it is suggested, since none is given in the paper.

The low frequency power factor of an insulating oil may be taken, for the purpose of this discussion, as proportional to the concentration, C_i, and the mobility of the ions in the oil. The mobility of the ions is in turn inversely proportional to the ion radius, r_i, and to the viscosity of the oil, η. Therefore

$$\delta = \frac{KC_i}{\eta r_i}$$

From studies made on insulating oils at The Johns Hopkins University (J. B. Whitehead, A.I.E.E. TRANSACTIONS, volume 52, June 1933, pages 667–81), it was shown that the product of the a-c conductivity and the viscosity of a given oil is essentially independent of temperature. From this and the above equation it follows that C_i/r_i is also practically unaffected by temperature change. Therefore, the principal effect of temperature change on the power factor is that due to the corresponding viscosity change, and it is not necessary to consider velocities of ionic dissociation or of dissociation of neutral molecules attached to ion nuclei. Therefore, if the power factor lags behind the median or steady state curve on rapid temperature change as here reported, it is indicated that the viscosity lags to the same degree. That is, if the temperature of the oil is suddenly raised, the viscosity does not immediately drop to its steady state value at the new temperature, but requires an appreciable time to do so. Since the temperature difference between the median and actual curves for a given power factor is about 8 degrees centigrade for a rate of temperature rise of 20 degrees centigrade per hour, the time for the change is about 24 minutes. Similarly, if the oil temperature is suddenly lowered, the viscosity requires the same time to rise to its new final value. This effect is akin to the supercooling of liquids, but is not so pronounced. Phenomena of this nature have been observed for other substances, notably glycerine. For the case of oils the effect may be entirely internal, i. e., an effect on the motion of only very small particles such as ions, and may not show up in the external characteristics as obtained in a viscometer (G. M. L. Sommerman, Franklin Institute *Journal*, volume 219, 1935, page 433).

J. C. Balsbaugh, N. D. Kenney, and Alfred Herzenberg: W. S. Baird has raised a number of very interesting questions. It is very difficult to see how the loop power factor characteristics as a function of cell temperature shown in figure 6 could be explained by thermal expansion and subsequent cell deformation concurrent with the heat cycle. As the temperature is changed, the capacitance of the cell will change slightly. However, this is relatively small with the type of cell design that is used. This change in capacitance over the complete temperature range has been measured and been found to be materially less than one per cent. The power factor of the cell as measured is, of course, referred to the cell capacitance at the temperature at which it is measured. Any power factor which is a function of cell temperature due to dimensional changes in the cell, could only be accounted for principally by changes in cell length or surface voltage gradients, which would be a second order effect.

Curve D of figure 6 represents the results of increasing and decreasing temperatures after heating by induction. That is, after the cell material is thoroughly degassed there is no difference in power factors for increasing or decreasing temperatures. Baird has raised an interesting point relative to the possible explanation of the power factor of air condensers as due to roughened surfaces. Our experience seems to indicate that there is more to the problem than this although this possibly may be one factor of importance. The nickel cylinders in the cells from which these test characteristics were obtained were originally baked out in a hydrogen atmosphere before installing in these cells and also were very highly polished so that it would seem impossible to attribute his suggestion for the cause of these losses. We are at the present time continuing this work and hope to be able in the future to account definitely for these measured losses in an air condenser.

The reason why it may not be desirable to inject an oil sample into a vacuum is that in cases where a test of a service aged oil is desired, the injection of this sample into a vacuum may significantly change those characteristics and therefore the measured power factor of the sample. However, there are cases where the injection of an oil sample into a vacuum would be perfectly appropriate.

With reference to G. M. L. Sommerman's comments, we think he has given an interest-

ing explanation for the cause of the loop temperature-power factor characteristic. Relative to the possibility of heat being imparted to the cell envelope at its center, we made temperature measurements at points other than those indicated in the paper to justify the conclusion that the oil temperature for the measured oil is between the plotted temperatures of figure 7. The center tube of the cell was closed at both ends of the cell, and temperature measurements in this section at the center of the cell showed a lower temperature for increasing temperatures than the lower values of temperature plotted in figure 7 for increasing temperatures.

Ultra-Short Waves in Urban Territory

Discussion and authors' closure of a paper by C. R. Burrows, L. E. Hunt, and Alfred Decino published in the January 1935 issue, pages 115–24, and presented for oral discussion at the communication session of the winter convention, New York, N. Y., January 22, 1935.

J. D. Kraus (nonmember): This interesting paper contributes much to the knowledge of ultra-short wave transmission. The great number of readings made during the survey in the Boston area provides a large amount of valuable data concerning propagation in urban areas.

Of particular interest in this paper is equation 5, in which the field strength is shown to be inversely proportional to the square of the distance. Using this equation for field strength, the radiation from an antenna to produce this field may be shown to be

$$W = \frac{1}{720\ \pi^2}\left[\frac{E\lambda d^2}{h_1h_2}\right]^2$$

where W is the radiated energy in watts, E the field strength in volts per meter, λ the wave length, d the radial distance from the radiator to the point where E is measured, and h_1 and h_2 the heights of the transmitting and receiving antennas, all measured in meters.

In figure 5, the authors have replotted data from a paper by Henry Muyskens and J. D. Kraus (I.R.E. *Proceedings*, volume 21, Sept. 1933, pages 1302–16) in which it appears that the data may be re-interpreted on the basis of an inverse-square-of-distance variation, as well as by an inverse-distance variation times an exponential attenuation factor. Substituting the field strengths from the inverse-square-of-distance curve in the above energy equation, one finds that the radiated energy from the antenna used by Muyskens and Kraus is within a few decibels of the proper magnitude provided the height of the transmitting antenna is measured from the ground. If the height is measured from the roof of the building on which the antenna was located, the computed power is about 15 decibels high or much in excess of the transmitter input.

In figure 2 of the paper, a distinction is made between 2 curves which are separated by 12 decibels. The lower one is called a "mean curve" and is drawn through the approximate average of the field strengths observed. The upper one is called a "level terrain curve." From the authors' data, it appears that in the case of their fixed location transmitter the "level terrain curve" agrees well with the radiated power if one measures the antenna height above the ground. When, however, the height of the transmitting antenna is measured from the roof, the proper value of radiated power is obtained only by use of field strength values from a curve which lies close to the "mean curve."

The antenna used by Muyskens and Kraus was of the vertical type using 2 half-wave elements excited and oriented so as to increase the radiation parallel to the ground. It was situated above the flat roof of a 4 story building which has closely adjacent a large number of other buildings of approximately the same height. According to Burrows, Hunt, and Decino, such a location should be important in determining the received field strengths. In order to obtain agreement between these data, it appears necessary to assume that the inverse-square-of-distance curve which the authors superimposed on the data of Muyskens and Kraus must correspond to a "level terrain curve." Since the points plotted by Muyskens and Kraus represent individual readings of field strength and those of the authors average values over a given radial distance, this assumption appears to be reasonable. On this basis, it may be said that the effect of the roofs under the transmitting antennas was the same in both cases.

Although it is pointed out that equation 5 has a number of limitations imposed by such things as widely varying antenna heights and ground conditions, it appears to come close to the actual picture under a considerable range of working conditions and should prove helpful in the predetermination of field strengths.

C. R. Burrows, L. E. Hunt, and Alfred Decino: While the authors believe that the method suggested by them for the estimation of the mean field strength to be expected for ultra-short wave transmission in urban territory will not be in error by a large amount in any practical installation, it should not be used indiscriminately. It is our opinion that the situations in the Ann Arbor and in the Boston experiments differed materially in that the building density is much less in the former case. This, together with the fact that the Ann Arbor antenna was located near a corner of the building and only a few yards above it, would make plausible the assumption of Kraus that in this case the height to use in the formula should be more nearly the height above the ground than the height above the roof. The fact that the power radiated in the Ann Arbor experiments could only be inferred from the power input to the transmitter makes a comparison of the 2 experiments on an absolute basis difficult.

The equation used in Kraus's discussion is based upon a doublet antenna. The antenna which he actually employed requires about half as much power to produce the same field.

The authors wish to call attention to an error in expressions $3a$ and $3b$ on page 117 of the paper. While this in no way affects the paper itself, the correct expressions are given here in order that any one who may have occasion to use them will not be led to an incorrect result.

$$E_0\left(\frac{4\pi h_1h_2}{\lambda d}\right)\sqrt{1+\frac{\epsilon^2\,(h_1+h_2)^2\,\lambda^2}{(\epsilon-1)\,4\pi^2h_1{}^2h_2{}^2}} \quad \text{(3a)}$$

$$E_0\left(\frac{4\pi h_1h_2}{\lambda d}\right)\sqrt{1+\frac{(h_1+h_2)^2\,\lambda^2}{(\epsilon-1)\,4\pi^2h_1{}^2h_2{}^2}} \quad \text{(3b)}$$

The factor 4 was incorrectly omitted from the denominator in each of these expressions in the paper.

Cathode Ray Tubes and Their Application

Discussion of a paper by J. M. Stinchfield published in the December 1934 issue, pages 1608–15, and presented for oral discussion at the electronics symposium of the winter convention, New York, N. Y., January 24, 1935.

C. Francis Harding (Purdue University, Lafayette, Ind.): No discussion of either the Dufour cathode ray tube (figure 3), with variable vacuum, nor the sealed tubes illustrated in figures 4 and 5 of the paper would be complete without mention of the early classic development of both of these types of cathode ray oscillographs by Prof. R. H. George of Purdue University, described in the A.I.E.E. TRANSACTIONS of 1929, which should appear in the bibliography.

Having developed special moving anode focusing devices and vacuum tube initiating circuits for the Dufour type oscillograph he has produced several complete oscillographs for the laboratories of Purdue University and some public utility and manufacturing companies. This special moving anode device permits not only the sharp focusing, from without the oscillograph case, of the electron jet upon either film or screen, but it also permits a wide range of accelerating potentials for all degrees of vacuum and different deflecting potentials. It is therefore a very flexible instrument. The automatic initiating device enables the electron jet to record within $^1/_4$ microsecond and prevents the fogging of the film. It takes advantage of the leading current from the antenna near the high potential line or test circuit resulting from a tuned capacitance and inductance; the potential induced by the rate of change of this current through another small series inductance leading still more the actual recording current. This leading potential neutralizes the bias of the initiating tube thereby recording the entire oscillogram of the steepest front transients.

C. S. Roys (nonmember): The use of the cathode ray oscillograph in its general application has been greatly restricted by the fact that one has not been able to view more than one wave at a time by means of a single tube, since it is apparently unduly complicated and expensive to build tubes with 2 or more electron guns. However,

this limitation has been overcome by a method developed in the school of electrical engineering at Purdue University, whereby 2 or more waves may be shown simultaneously in their correct relative phase positions using the ordinary type of cathode ray tube.

In the arrangement actually constructed, 2 signals are impressed across the input terminals of 2 separate single stage amplifiers that utilize type 57 pentodes. The sweep circuit is coupled to one of the signal circuits by means of a triode, this method resulting in an amplification of the synchronizing impulse, accompanied by a corresponding attentuation of the distortion in the signal circuit that usually results from the sweep circuit phenomena.

The output to the sweep circuit, in turn, is coupled to the grid circuits of 2 gaseous triodes that are arranged in a manner similar to the simple, single phase inverter. As a result, first one gas triode operates and then the other, causing the screen grid potentials of the 2 pentodes to become alternately positive and negative in succession and thus to block first one amplifier and then the other. Since this switching circuit is locked in with the sweep circuit, and the latter in turn with one of the signals, the final result is that first one of the signals is shown and then the other. In the event that the frequencies of the 2 signals are simple multiples of one another, the 2 waves will appear stationary, and furthermore if the sweep frequency is above 30 cycles per second, the 2 waves will appear to be shown on the screen simultaneously, due to the persistence of vision. It is also possible tc extend the general method to the showing of any number of waves simultaneously, special emphasis being placed upon the 3 phase case.

R. H. George (Purdue University, Lafayette, Ind.): I wish to call attention to another type of sealed off cathode ray tube, employing a modification of the electrostatic and gas method of focusing, described in a paper "A New Type of Hot Cathode Oscillograph and Its Application to the Automatic Recording of Lightning and Switching Surges," A.I.E.E. TRANSACTIONS, volume 48, July 1929, pages 884–90.

The sealed off tube was developed at the engineering experiment station, Purdue University, for the purpose of television reception. A schematic diagram of the electron gun and deflecting plates is shown in figure 1 of this discussion.

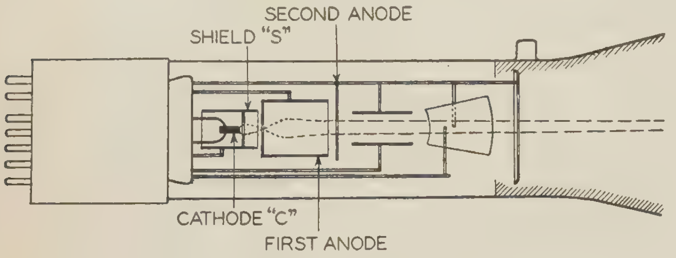


Fig. 1. Schematic diagram of the electron gun and deflecting plates of a cathode ray tube

Regarding auxiliary apparatus, the writer has found an electron tube switching circuit for showing 2 different waves on successive sweeps very useful, both for laboratory and commercial applications. This circuit, which was devised by C. S. Roys and H. F. Mayer, has been further improved by H. J. Heim, G. E. Happell, and the writer until it will operate at sweep frequencies as high as 14,000 cycles per second. With this circuit it is possible to show the proper phase relation between 2 waves at frequencies as high as 70,000 cycles per second.

The "Thyratron" Motor

Discussion and authors' closure of a paper by E. F. W. Alexanderson and A. H. Mittag published in the November 1934 issue, pages 1517–23, and presented for oral discussion at the electronics symposium of the winter convention, New York, N. Y., January 24, 1935.

Philip Sporn (American Gas and Electric Co., New York, N. Y.): In spite of the many known methods for obtaining speed variation of a-c motors, there has been no really satisfactory variable speed motor equal in ease of control and reliability to the d-c shunt motor. In the power industry we have suffered from that, not only because of its retarding effect on the application of electric drive in many cases, but also more directly—in the steam generating station, for example. Thus, for boiler fan drive there have been tried single constant speed motors with damper or vane control on the fan end, one slip ring motor with armature control, 2 slip ring motors each with armature control, each motor covering a portion of the speed range, hydraulic variable ratio couplings, Rossman drive, straight d-c drive, and heaven knows what else. All of these methods have been proved to possess one or more serious disadvantages.

It was with all these thoughts in mind, coupled with the further fact that we have been intensely following electronic applications, and that we are firm believers in the old saying that the way to begin is to commence, that we ordered a 400-hp 2,300-volt, 3-phase 60-cycle "thyratron" motor for induced draft fan service at one of our power plants. This motor has been built and tested but has as yet not been placed in service; it is, therefore, too early to give any operating experience.

The operation of the motor on test, and it was put through very stiff paces, was however very satisfactory. For example, the motor was started with various combinations of tubes out of service, and was even started on single phase power while connected to a load equivalent to the fan load which it is to drive. The motor performed satisfactorily under all of these methods of operation. Undoubtedly the motor will seldom, if ever, be called upon to meet some of these contingencies in actual practice. All of these data it is hoped to present in more complete form in the near future.

The motor itself is simple and rugged; in appearance the only apparently novel feature is a distributor mounted on the shaft for controlling the firing of the tubes. It would seem that the only problem here is to keep the distributor properly enclosed so as to keep out dirt and dust, with the possibility of improper operation from this cause. Two sets of distributor segments are required at present, one set for starting and one for running; it is hoped that further developments will enable one set to be dispensed with, thus simplifying control.

From all the above it is evident that the only unknown in connection with the whole job is the question of tube performance, and particularly tube life. Undoubtedly the tubes available today leave a great deal to be desired, both from the standpoint of life and uniformity, but in fairness to the tube designer, it must be stated that no real progress can be expected until tubes by the hundreds and thousands are put to work in the field and their life histories, including their diseases and complexes, intelligently recorded. This, it must be apparent, is a prerequisite to an intelligent diagnosis and eventual cure. It is here, in the finding of proper tube application, that the utility engineer can do his share in bringing to a realization the promise of advancing the art of generation, distribution, and utilization of electric energy that a full development of the heavy power tubes holds forth.

The cost of this motor is at present higher than that of other variable speed drives, but there is nothing fundamental in this; it will change as tube costs come down, as they surely will, when demands for motors of this type and for other heavy electronic equipment develop. This motor now offers a simple variable speed a-c drive. When the developments mentioned above are realized, it ought to become an inexpensive one also.

L. R. Ludwig (Westinghouse Elec. and Mfg. Co., E. Pittsburgh, Pa.): This motor is made to operate successfully by using circuit means for the suppression of tube faults rather than by eliminating them in the tubes themselves. Although such an arrangement would be satisfactory from a standpoint of operation of the equipment without shutdown, it would seem to be hazardous for the tubes if they are of the thermionic type. The failure known as arcback presents only a small problem in an inverter or commutator tube arrangement, because the fault current is soon reduced to zero by the nature of the circuit, and such a failure would hardly affect the thermionic tube. The type of failure known as loss of grid control, however, may be precipitated by backfire, and even when reactors are used to limit the current to several times normal for a half cycle or so a very unkind blow is given to the cathode of the thermionic tube. If this happens once a day, the life of the tube might be considerably shortened, and I would like to ask if the authors have made life tests to deter-

mine the effect of what might be termed incipient failures, corrected by circuit reactors.

During the development of similar "ignitron" equipment, it was not found necessary to resort to circuit suppression of faults in order to obtain substantial ratings, but schemes for this purpose were devised some time ago, and it might be of interest to mention them since they differ somewhat in principle from the simple introduction of reactance. An inverter can be caused to "ride through" a tube failure, if, when such a failure occurs in one tube, the next tube to carry current is automatically permitted to fire earlier than usual. In this way, the fault current in the tube which failed can be commutated to the next tube. If next the firing point of the successive tubes is gradually retarded to normal, the failure passes by, practically unobserved. With the mercury pool cathode there is, of course, no hazard to the tube.

I would also like to ask the authors if the published performance curves are the results of test or calculation.

The economic practicability of this type of motor seems questionable with tubes in their present state of development. As stated by the authors, their circuit really serves the double purpose of rectification and inversion. Rectifiers are available at a cost comparable to that of a rotating machine converter, and they operate quite satisfactorily although at a power factor poorer than that of a synchronous converter. Inverters, however, will not operate except with the power factor completely corrected, and consequently the inverter tubes cannot be compared in cost with a rotating machine converter, but with the commutator only of that machine. This is very clear from the authors' circuit, in which the commutator simply has been replaced by tubes. At the present time, the tube equipment is considerably more expensive than the commutator, and it would seem that there would be an economic gain if a d-c motor were supplied through a tube rectifier, instead of using a completely commutatorless motor.

P. M. Currier (General Electric Co., Schenectady, N. Y.): In mentioning the characteristics of this motor the authors state that it "operates on an a-c power supply—without any reference to synchronism with the a-c system." Immediately this brings to mind the feature of speed control. I should like to point out another feature which may not be so obvious, i. e., the possibility of its becoming a useful component of an electrical reduction gear.

For example, in propulsion equipment, from the viewpoint of weight, space, and efficiency, it is desired to have the power generating equipment run at as high a speed as possible, while the motor equipment has a fixed maximum speed. If direct current is used for the electrical reduction gear it has the advantage of variable speed but the voltage used must be relatively low and direct current generators are limited in speed to a relatively low value. If alternating current is used it has the advantage of being able to operate at high voltage, but has the disadvantage of not having a variable speed control and of requiring a motor with a large number of poles and a large diameter. A high speed turbine generator of higher than normal frequency feeding a motor of the type described appears to utilize the advantages of both of these schemes without encountering the disadvantages. However, this equipment has not been developed yet to a point where it could be used for large ships.

R. E. Hellmund (Westinghouse Elec. and Mfg. Co., E. Pittsburgh, Pa.): In the papers by Alexanderson & Mittag and Wagner & Ludwig 2 kinds of arrangements, the work for which was done in 2 different laboratories, are described for adjustable speed motors operated by means of electronic converters. Although work of this character is highly desirable for the reason that something of practical value may eventually result therefrom, it should be pointed out that with the knowledge available at present there seems to be little prospect of a broad general application of these or similar motor arrangements. The situation surrounding these electronic converter motors is somewhat akin to that found in connection with polyphase a-c commutator motors. It will be recalled that a number of years ago and extending over a considerable period of time, many different types of a-c commutator motors were proposed and investigated. However, but few of these types have found any practical application, and the few types that are in practical use have not been applied very extensively. The reason for this is that these commutator motors usually require a larger armature volume (D^2L) than the induction motor and also large commutators and numerous brushes, all of which result in a very high first cost. In addition, these motors are handicapped by the necessity of rather costly brush replacements and commutator maintenance. Furthermore, since the armatures of such

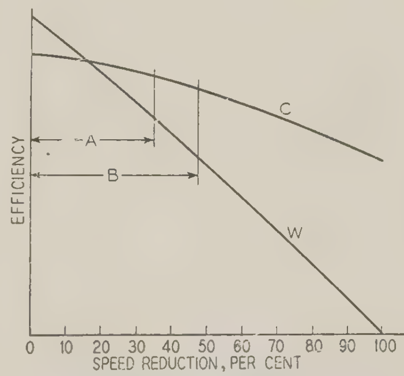


Fig. 1. Comparison of efficiencies of wound secondary and commutator motors

motors must be designed for low voltage, the ohmic drop in brush contacts, together with the brush friction losses, results in a rather low efficiency.

In figure 1 of this discussion, curve W is representative of the efficiency of a wound-secondary motor over the entire speed range and, as is well known, the efficiency drops appreciably with the speed. However, the commutator motor on account of the losses mentioned has a rather low efficiency even at full speed, but the drop in efficiency with reduced speed is somewhat less, as indicated by curve C. If we assume a motor operating somewhat uniformly over the speed range A, it is obvious that over this range a commutator motor will not show any advantage in the way of efficiency. If the maintenance of brushes and commutators and also the amortization of the first cost are taken into account, it is likely that within the speed range B a simple induction motor can be operated as economically as a commutator motor. In other words, economic application of the commutator motor is confined to a few cases where a greater speed range is required and where operation at lower speeds predominates, and to those cases where the steep speed torque characteristic of the induction motor is objectionable.

Unfortunately, the situation does not seem any more promising for the motors described in the papers. As pointed out in the paper on the tube controlled motor, the various motor windings carry current only part of the time, which in turn leads to higher copper losses and consequently necessitates a large armature volume and high motor costs. The addition of electronic devices further increases the first cost. It is also known that, particularly with hot cathode tubes, there will be certain replacements necessary, resulting of course in increased maintenance expense. The efficiency is unfavorably affected by the arc drop of the electronic devices, and in the case of hot cathode tubes by filament losses also. With the arrangement shown by Wagner and Ludwig the motor losses and motor dimensions work out somewhat more favorably and the losses in the hot cathodes are eliminated. However, the particular arrangement shown in the Wagner-Ludwig paper requires a rectifier in addition to the inverter if the primary source of power is alternating current. This means more arc drops and higher first cost than shown in the paper, although neither in excess of that with the Alexanderson-Mittag arrangement. However, the smaller motor dimensions are offset by the necessity of using a transformer with the arrangement shown. There is, of course, the possibility of using "ignitrons" in a scheme similar to that shown for the "thyratron" motor. In this connection it may be pointed out that while the circuit arrangement of the Alexanderson-Mittag paper gives series characteristics with either type of tube, the arrangement described in the Wagner-Ludwig paper give shunt characteristics. As the latter paper deals principally with an inverter, no starting arrangement for the motor has been described but suitable provisions are being developed.

The influence of the arc drop can of course be minimized by using a relatively high voltage, such as 4,000 volts as the motor described by Alexanderson and Mittag. The high voltage is not a great drawback in motor designs for large ratings, and therefore large motors for application in central stations, as mentioned in the discussion by Philip Sporn, may represent one of the more favorable applications for motors of this kind, assuming of course that large speed reductions are necessary for an appreciable part of the time. However, it is believed that even for large motors a good case cannot be made in applications where weight and space limitations are of importance, as, for instance, in railway and ship propulsion work. For the latter application in particular, it seems difficult to find any economies in either first cost or operating costs brought

about by the electronic converter which would more than compensate for the extra cost and losses incident to the use of the inverter. With small motors the arc drop represents an appreciable loss if the motors are designed for low voltages, such as 220 volts, while any attempt to design small motors for high voltages usually leads to very uneconomical designs on account of the poor space factor in the slots. Therefore, with conditions as they can now be foreseen, it appears that these motors with electronic devices will find very little application and only in cases where conditions are particularly favorable.

R. W. Wieseman (General Electric Co., Schenectady, N. Y.): The operation of an a-c motor of this type can be explained by considering a rotating armature machine whose armature winding has 2 independent wye connected circuits as shown by figure 2 of this discussion. The terminals of the 2 windings are connected to 2 segmental slip rings which have 3 segments per pair of poles regardless of the number of armature conductors. For simplicity the neutrals of the windings are connected together and the field circuit is omitted. The field winding may be connected in shunt or in series with the line. The poles and winding represent the motor and the segmental collector rings explain the functions of the tubes and their grid control apparatus including the distributor on the motor shaft.

If direct current is applied to the brushes, current will flow in phases 1 and 2′ as indicated, and the rotor will tend to move clockwise. As the armature rotates, one of the brushes will contact with the next segment and the current will be transferred from phase 1 to phase 3. The sequence of commutation at 60 degree intervals is as follows:

Angular Displacement, Degrees	Current in Phases	Commutation From
0	1 and 2′	
60	3 and 2′	1 to 3
120	3 and 1′	2′ to 1′
180	2 and 1′	3 to 2
240	2 and 3′	1′ to 3′
300	1 and 3′	2 to 1
360	1 and 2′	3′ to 2′

If the currents are traced through the windings in this manner, it will be found that the current in an armature coil never reverses and that a coil conducts current only $^1/_3$ of the time (but during this interval it can carry a higher current than its normal continuous current). The armature copper loss is about twice as much as when the same motor is operated as a conventional synchronous motor with the same output.

To allow sufficient time for the motor counter voltage to commutate the current from one motor phase to another by grid commutation above $^1/_3$ speed, the brushes are advanced as shown in figure 2. This advances the phase position of the motor current wave so the motor draws leading power factor currents whereas the tube circuit draws lagging power factor currents. At starting or at very low speeds within the range of anode commutation, the brushes may be shifted back toward their neutral position and the motor torque substantially increased. Thus by shifting the brushes on the motor distributor the torque per unit current can be made higher at starting and at very low speeds than at full speed. At all speeds the motor torque varies somewhat with the rotor position and the magnitude of the torque variation increases as the brush shift from the neutral position increases. No dead points occur with a suitable arrangement of the grid control circuit.

This type of motor has advantages when large speed variations are required. Its speed is not governed by the supply frequency nor by the limits of pole flux variation nor by commutation difficulties. It can be operated from a constant frequency single phase or polyphase supply at any speed from a few revolutions per minute up to its rated speed by simply moving the

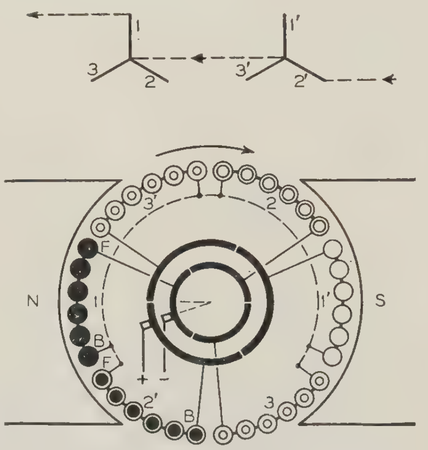


Fig. 2. Diagram illustrating operation of motor

controller. No power is lost in rheostats of any kind in the motor circuit.

Figure 3 of this discussion shows the characteristics of a 400 horsepower, 625 rpm motor for driving a blower. The lower curve shows the required blower horsepower for a speed range of from 625 to 350 rpm. The line kilovoltamperes, power factor, current, controller setting, and over-all efficiency of the set for this speed range are given. From 400 horsepower motor output at 625 rpm down to 75 horsepower at 350 rpm, the over-all efficiency drops from 90 to 83 per cent, a decrease of only 7 per cent. The larger the speed range of this type of motor, the greater is its advantage over conventional variable speed motors.

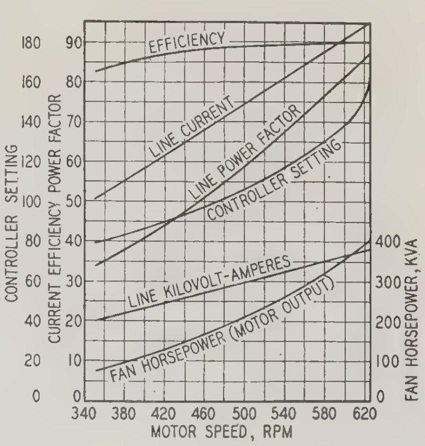


Fig. 3. Characteristics of 400-horsepower 625-rpm 2,300-volt tube-controlled a-c motor for driving a blower

Distributor brush setting 48 degrees advanced

E. F. W. Alexanderson and **A. H. Mittag** (both of General Electric Co., Schenectady, N. Y.): We have had experience with loss of grid control or firing of tubes out of turn. A tube approaches loss of grid control gradually and after a half cycle of such failure it usually operates without failure for a considerable length of time, perhaps a whole day, before there is another failure. Of course, as time goes on these failures become more frequent. The current limiting reactor shown in figure 1 of the paper limits the current for this type of failure as well as for arcbacks and prevents a shutdown of the motor so long as these failures do not occur in too rapid succession. Ample warning is therefore given and at the first opportunity such a tube should be removed.

A tube controlled motor supplied from a d-c source of power can be started from standstill. The commutation of current can be accomplished at standstill and at low speeds with the aid of static condensers.

The performance curves shown in the paper are the results of tests made on our 4,000-volt 400-hp motor.

Industrial Electronic Control Applications

Discussion and authors' closure of a paper by F. H. Gulliksen and R. N. Stoddard published in the January 1935 issue, pages 40–9, and presented for oral discussion at the electronics symposium of the winter convention, New York, N. Y., January 24, 1935.

W. D. Cockrell (nonmember): Gulliksen and Stoddard are to be commended on having written an excellent and instructive article. An interesting point is the large number of copper oxide rectifiers used in the circuits described, which would seem to indicate that the reliability and aging characteristics of these devices have been greatly improved in the last few years.

The diagrams of most of the photoelectric relays include a winding for the light source within the relay enclosing case. There is some question as to whether in general it is preferable to provide a winding for the light source at the relay, since because of the low voltage and high current taken by the light source lamps the drop in the lead may prove excessive. There is also the consideration that if a small transformer is provided at the light source it may be supplied directly from the standard 110 or 220 volt lines which are most convenient to the light source location.

There are, also, a few points in the individual circuits on which the authors' comments are desired. Figures 1, 7, 9, and 11 of the paper show copper oxide rectifiers in the photoelectric tube circuit, although the tube operated by the photoelectric tube has an alternating current supply. Since the speed of operation is determined by the frequency of the alternating power supply,

and since the grid impedance of the vapor discharge tube must be low enough so that for normal lengths of photoelectric tube cable the capacity effect will not be prohibitive, it would seem that the addition of the rectifiers to produce a direct voltage for the phototube is a needless complication of the circuit.

Regarding the lock-in type of controller shown in figure 6, has there been any difficulty from the *KU*-627 tube failing to commutate? Is an auxiliary reactance used in practice to facilitate this action or is the inherent reactance of the circuit sufficient? It would seem that 2 features would tend to cause erratic timing with this particular circuit. The actual instant of pickup of the solenoid would be somewhat dependent on the heating and subsequent resistance of its coil. Also, since the timing contactor can charge up only to the cathode potential of the *RJ*-563 tube, its potential is changing very slowly as it approaches the proper grid potential to energize the solenoid.

It is noted that the electron voltage regulator shown uses a dry battery as the reference voltage. Our practical experience has shown that it is very difficult to have these batteries checked and replaced properly and it has been found best to eliminate batteries from any industrial control equipment in so far as possible.

In the register regulator shown in figure 21 it is seen that a double photo-electric tube bridge is used. Are matched tubes used for this application? If this is not the case, is not the adjustment of the unit very critical and tedious? And is not the adjustment rather critical to the difference in aging in the light sources or in drift in photoelectric tube sensitivities? Are the photoelectric tubes used here of the gas filled or the vacuum type? The voltage characteristics of the gas filled tubes would tend to produce degenerative effects, i. e., the voltage increase across the darkened tube would tend to diminish the expected current change. The vacuum type, of course, is but a fraction as sensitive as the gas filled photo-electric tube.

R. L. Goetzenberger (Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.): Another practical application of electronic control, and incidentally one which has been adopted as a standard of combustion safeguard, is incorporated in a system involving the closing of fuel valves the instant that flame ceases, consequently guarding against explosions of unburned gas which might accumulate in a combustion chamber fired with gas or oil fuel. In functioning it depends upon the fact that a flame is a slightly ionized gas mixture which will conduct a small current. An electrode, either a rod of high temperature alloy or a ceramic sleeve, is projected into the flame. Current is carried by the flame to ground through the burner with which it is in actual contact. An industrial electron tube magnifies this current to close a relay controlling the motor or solenoid operating the fuel valve. If the flame fails to impinge on the electrode the bleeding off of the charge to ground ceases, the tube passes no current, and the relay opens, de-energizing the valve with the result that the flow of fuel to the burner is stopped.

Since this system utilizes the flame itself as a conductor for the current required in operation, it offers certain definite advantages over other types of combustion safeguards, such as:

1. Instantaneous response.
2. Positive response unaffected by light, heat, or radiant energy; affected only by flame. Incandescent refractories or heat absorption cannot cause false operation or delayed response. Works equally well in visible or invisible flames.
3. Independent of size of flame, hence suitable for high-low burners. It is necessary only that the flame electrode extend into some portion of flame present in both high and low operation.
4. Applicable for use with any existing control system where alternating current is available.
5. Closed circuit protects itself against its own failure. Any damage to tube, break in wire, short circuit, or defective connection anywhere in the safety system shuts down the burner immediately.

C. Stansbury (nonmember): I believe that all engineers who have had practical experience in the application of electronic devices in industry will agree with me that the use of such devices accentuates the already pressing need for more competent plant electricians. It is the common experience of control engineers that the average plant electrician does not seem to be capable of understanding the functioning of an ordinary lockout self-starter, and that being the case it may readily be imagined how helpless such men would be when faced with the necessity of intelligent maintenance work on apparatus of the character described in this paper. It is quite common to find men in charge of mechanical apparatus who are skillful and intelligent mechanics, but even a rudimentary knowledge of electrical phenomena does not appear to be a requirement in the selection of the average plant electrician. This constitutes a really serious impediment in the task of the exploitation of industrial electronic apparatus.

It has been mentioned that an electronic device may be made entirely safe by so arranging the circuit that the failure of the tube to conduct shuts down the system and gives a safe condition. This brings up one of the most serious defects of tubes for industrial application in that a tube may either fail to conduct when it should, or fail to block the conduction when called upon to do so. Such a possibility exists in any device used to open and close circuits. In the case of an ordinary magnetic contactor of normally open type, the probability of the contactor failing to open when the coil is de-energized is very slight. The probability of the contactor failing to close when the coil is energized is somewhat greater because of the possibility of a burned out coil, low operating voltage, or defective contacts in the circuit. It is a fundamental principle of ordinary magnetic control practice, therefore, to make the safe condition correspond to de-energized operating coils so that the dependence for reliability as regards safety is placed essentially on gravity or at least a substantial spring.

However, a tube will always ultimately fail to conduct when it wears out in service so that circuits have to be designed to give the safe condition with the tube not conducting. There results the necessity for means for blocking conduction in the tube when not desired which shall be of the same order of reliability as those used with the magnetic device, if equivalent safety is to be attained. No such reliability in this respect can be claimed for tubes at the present time and the result is a serious limitation on their application.

F. H. Gulliksen and **R. N. Stoddard** (both of Westinghouse Elec. and Mfg. Co., E. Pittsburgh, Pa.): In reply to Cockrell's remark concerning the location of the light source transformer, it may be of interest to point out that in most installations space is at a premium at the location where the light source is mounted. For this reason it is desirable to make the light source as small as possible, and this can be easily done by omitting the special light source transformer. It is also often desirable to make sure that the photoelectric relay and the light source are excited from the same a-c source in order to prevent independent variations in voltage which might affect the operation of the equipment. The voltage drop in the light source leads is compensated for by the provision of voltage taps on the transformer.

The purpose of the copper oxide rectifiers in figures 1, 7, 9, and 11 is to supply continuous voltage to the photoelectric tube. Alternating voltage of course could have been used, but in that case the length of the tube leads must have been limited to perhaps 15 or 20 feet, owing to the effect of the capacity between the leads. This distributed lead capacity, which would be in parallel with the tube, would produce a phase shift in the tube circuit which would affect the sensitivity and the calibration of the relay. By using a d-c supply this detrimental capacity effect is avoided. The purpose of the continuous voltage is not, as assumed by Cockrell, to increase the operating speed of the relay, which as stated by him is limited by the 60 cycle anode supply voltage.

No difficulty has been experienced with the commutation of the *KU*-627 tube in figure 6. If the resistor in series with the anode is made sufficiently low compared to the condenser charging resistor, the anode-cathode voltage of the tube will drop below the arc drop of the tube and the current through the tube will be interrupted. The effect of temperature variations of the solenoid coil is minimized by the resistor connected in series with the solenoid coil.

The ohmic resistance of this resistor is approximately 10 times the solenoid resistance, and slight changes in solenoid resistance, therefore, will not change the current through the solenoid appreciably. The solenoid is normally energized, and becomes de-energized when the photoelectric controller operates. Because the total de-energizing time of the solenoid is approximately 0.5 cycle, a few per cent variation in de-energizing times does not have any appreciable effect on the operation of the equipment.

The writer agrees with Cockrell that it would be desirable to eliminate the batteries in the voltage regulators. No practical regulator, however, has yet been developed with a sensitivity of $^1/_{10}$ of one per cent without using a battery. The life of a dry cell is between 8 and 12 months, and the replacement of this cell is, therefore, no serious drawback.

Matched tubes are not necessary in the register regulator in figure 21, because a

balancing potentiometer is supplied to compensate for variations in tube characteristic. It is desirable, however, to use tubes as nearly matched as possible. Vacuum tubes must be used in this balanced circuit. Due to the characteristic of the circuit, the over-all sensitivity of the scanner, using 2 vacuum tubes, is the same as the sensitivity of a single photoelectric tube scanner using a gas filled tube; even though the sensitivity of the gas filled tube is 5 times the sensitivity of the vacuum tube. The reason for this is that when the illuminaton of one photoelectric tube is increased, the voltage across this tube is decreased and the voltage across the other photoelectric tube is considerably increased. Because the circuit is designed so that the tubes operate normally above the saturation voltage, it is obvious that a gain in sensitivity is obtained.

Application of Electron Tubes in Industry

Discussion of a paper by D. E. Chambers published in the January 1935 issue, pages 82–92, and presented for oral discussion at the electronics symposium of the winter convention, New York, N. Y., January 24, 1935.

R. L. Goetzenberger: See discussion, page 753.

The "Ignitron" Type of Inverter

Discussion and authors' closure of a paper by C. F. Wagner and L. R. Ludwig published in the October 1934 issue, pages 1384–8, and presented for oral discussion at the electronics symposium of the winter convention, New York, N. Y., January 24, 1935.

R. E. Hellmund: See discussion, pages 751–2.

C. C. Herskind (General Electric Co., Schenectady, N. Y.): The authors point out that in order that a mercury arc rectifier may be capable of operating as an inverter, it is essential that the anodes have a short deionization time. Large size metal tank rectifiers equipped with control grids, and having an estimated deionization time of 250 microseconds or less, have been in operation for a number of years. It can be shown that a deionization time of less than 250 microseconds is not necessary for operation as an inverter at normal frequency.

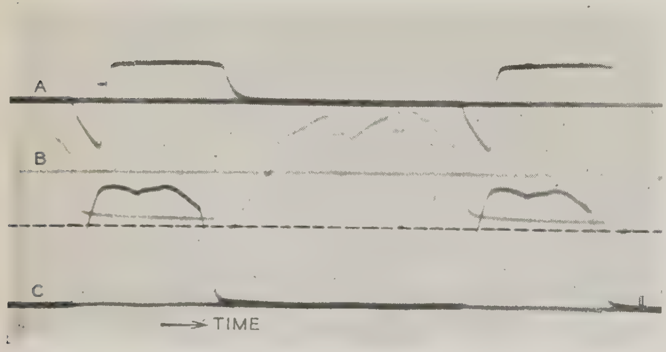
Expressed in angular units, at 60 cycles, a deionization time of 250 microseconds corresponds to approximately $5^1/_2$ electrical degrees. If it is assumed that the inverter is operating at the commutation limits, it is necessary to advance the grid excitation only about from 2 to $2^1/_2$ degrees in order to obtain sufficient time for deionization, as a small increase in the angle of grid advance causes a considerable reduction in the overlap period. The variation in the angle of overlap with the angle of grid advance for an inverter has been shown on curves given in the paper "Grid Controlled Rectifiers and Inverters," C. C. Herskind, ELECTRICAL ENGINEERING, June 1934, pages 926–35.

When using valves having deionization times of 250 microseconds or less, the accuracy of anode starting is more important than is the length of the deionization period. Experience with a large number of grid equipped rectifier units indicates that there may be a gradual contamination after a long period of operation, and that any foreign matter within the vacuum chamber tends to accumulate in the cathode region and not at the anode. From this we might logically assume that a control device located in the anode region would be more reliable than one in the cathode region. Experience further shows that the grid characteristics become subject to less variance the longer a rectifier has been in operating service. I would like to ask what is the effect upon the ignitor of contamination of the type which might be obtained in normal rectifier operation.

The authors state that the application of the mercury pool cathode inverter has been restricted by the limitations of the grid type of control, due to the grid construction being cumbersome and costly. I wish to point out that over 90 rectifiers equipped with grids suitable for grid control have been sold in this country alone in direct competition with uncontrolled rectifiers for applications not involving use of grid control.

The accompanying reproduction, figure 1, of an oscillogram shows the anode current and voltage wave forms of a 6-phase 1,500-kw 3,000-volt mercury pool rectifier, operating as an inverter at a d-c input of 1,000 amperes and 2,500 volts. This unit was operated at 2,500 volts instead of 3,000 volts, not because of any limitation of the rectifier, but because of the limitations of the available transformer and loading equipment.

The authors state that the control grid is often a source of trouble within the tube since conditions are difficult to avoid under which it will be burned by the arc. I wish to point out that very little trouble has been experienced with rectifiers equipped with grids; and further the danger of burning may be avoided by using grids constructed of graphite, which is practically indestructible as regards burning.



A. Grid current

B. Anode to cathode voltage (using capacitor in series with potential transformer. Cathode voltage indicated by dotted line)

C. Anode current

Fig. 1. Oscillogram showing anode current and voltage waves on a 6 phase inverter with input of 1,000 amperes, 2,500 volts direct current

C. F. Wagner and **L. R. Ludwig** (both of Westinghouse Elec. and Mfg. Co., E. Pittsburgh, Pa.): We are in agreement with Herskind that a deionization time of less than 250 microseconds is not necessary for the successful operation of an inverter. We cannot see how this can be construed to be inconsistent with the statement that a small deionization time is essential. In conventional rectifiers these small deionization times are obtained by the use of grids and are consequently bought at the expense of higher arc drops. Inherently, a rectifier using the "ignitron" principle can be built with a smaller arc drop.

Herskind also refers to our statements regarding the limitations of grids and the burning of grids in conventional rectifiers. We do not question that it is possible to obtain grid structures which are free from burning or backfire difficulties. However, the presence of these grids necessarily increases the arc drop, and consequently it is of advantage to dispense with the grid if equal or more reliable control is available in another way. It is quite probable that even with "ignitrons" certain applications will require the presence of grids, but even so, the grid structure with the "ignitron" will be smaller than the grid structure for a corresponding conventional grid-controlled rectifier.

From laboratory tests and a large number of rectifier hours in the field we have found that the ordinary cathode contamination collected during normal operation has no appreciable effect upon the ignitor or its starting function.

Ratings of Industrial Electronic Tubes

Discussion of a paper by O. W. Pike and Dayton Ulrey published in the December 1934 issue, pages 1577–80, and presented for oral discussion at the electronics symposium of the winter convention, New York, N. Y., January 24, 1935.

R. E. Hellmund (Westinghouse Elec. and Mfg. Co., E. Pittsburgh, Pa.): I wish to indorse heartily the efforts of the authors to bring about standardization of industrial electronic devices and to emphasize in particular the necessity for establishing standard ratings by the "preferred numbers" system as touched upon in the last part of the paper.

Much enthusiasm has been manifested by engineers in the past over the possibilities of

electronic devices for application in the industrial and power fields and the papers presented during this convention present new evidence of such possibilities. Nevertheless the total number of applications for each of the many possible types of devices is so far decidedly disappointing. The reason for this is that the cost of electronic devices for fields other than radio is too high, this high cost of course being brought about by the fact that there are so many types and sizes that quantity production for any one of them is impossible. Therefore, nothing can contribute more toward furthering increased application than standardization. Unfortunately it will be necessary to have many types of tubes to fill the large variety of requirements and therefore it is essential that but few standard ratings for each type be selected if an unduly large total number of standards is to be avoided.

Fortunately the conditions applying to tubes favor the use of but few ratings with large steps between them. Figure 1 indicates in a general way the cost of different

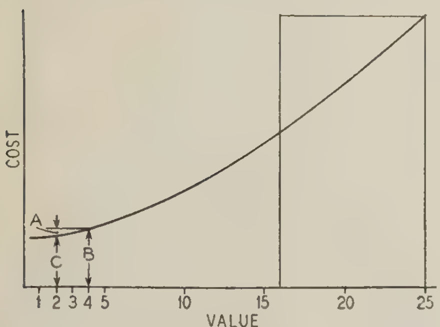


Fig. 1. General variation in cost of different sizes of tubes

sizes of tubes. It will be seen that for the lower ratings this cost curve is very flat, because for these smaller tubes the labor content forms the largest part of the cost, the material being of secondary importance. Let us assume that ratings were established at values 1 and 4, meaning a 300 per cent step between them. If, then, in an application requiring a tube of the value 2, a tube of the value 4 were used, the increased cost of this tube over that of the value 2 tube would be represented by the very small amount *A*. However, very appreciable savings would result through having to carry on less development, keeping fewer stocks, and being able to manufacture the value 4 tube in larger quantities. For the higher ratings, where the material content is of relatively great importance, it may of course be necessary to use somewhat smaller steps, such as the 60 per cent step indicated between the values 16 and 25.

I am thoroughly convinced that little progress will be made in the application of electronic devices unless early and effective standardization is worked out and relatively few ratings chosen along the line just indicated so as to lower costs and improve quality. I wish to support the authors in their recommendation that such ratings be selected from the preferred numbers series, because in such new standardizations these numbers can be used without the usual difficulties arising from interfering with already established standards.

A New Timer for Resistance Welding

Discussion of a paper by R. N. Stoddard published in the October 1934 issue, pages 1366–70, and presented for oral discussion at the electric welding session of the winter convention, New York, N. Y., January 23, 1935.

W. C. Hutchins (nonmember): The author has stated in connection with the use of electron tubes for resistance welding that "welding current always begins at a predetermined point on the voltage wave regardless of time of closure of the initiating switch." Also we know this type of tube stops passing current at the zero point on th current and following the removal of igniter power.

The mere mention of these facts does not convey their importance. True enough they imply that accurate timing can be accomplished using a timer which is not so accurate. In other words the time during which power is supplied to the welder will be the interval from the predetermined point on the voltage wave to a zero point on the current wave. In order to get perfect timing, it is then necessary to have a timer accurate only within approximately a half cycle.

Consistent firing or starting at a predetermined point on the voltage wave is very important for another reason, that of minimizing transient currents which are so common with the ordinary mechanical or magnetic interrupters. Even though accurate timing is accomplished, if transient currents frequently occur welds made in only 2 or 3 cycles probably will be inconsistent. In one instance, the user of a seam welder equipped with a mechanical nterrupter was getting considerable variation in the quality of his welds and also the welding transformer overheated to a dangerous temperature. To improve the weld quality, a tube control was applied. The result was that rejects were practically eliminated and the welding transformer no longer overheated; in fact it did not reach its rated temperature. The reason for the lower operating temperature was the elimination of the transient currents giving a lower average current in the primary of the welding transformer. From this it may be concluded that with the electron tube control a given design of welder may deliver more power than when ordinary mechanical interrupters are used.

The factors that determine the most effective point on the voltage wave for beginning passage of current are power factor of load, exciting current, and residual flux.

When spot welding, the primary and secondary circuits are opened between each weld. Transients which may occur when making a weld are consequently eliminated before the succeeding weld. The elimination of a possible cumulative action of transients permits considerable variation in the adjustment of the starting point.

When seam welding, the secondary circuit of the welding machine is usually not opened for several hundred impulses of power. Any unbalance remaining from one impulse is added to the succeeding unbalanced impulses. This cumulative action might eventually result in so large a transient as to cause poor welding. Therefore, it is necessary to adjust the point of firing much more accurately with seam than with spot welding, and it is the writer's belief that this can be satisfactorily accomplished only through the use of electron tubes. Mechanical devices for interrupting the welder current directly would naturally wear and require frequent adjustment. Even then it would in all probability be impossible to adjust for the exact starting point.

R. E. Hellmund (Westinghouse Elec. and Mfg. Co., E. Pittsburgh, Pa.): Spot welding by means of electronic devices has been found particularly advantageous in the welding of thin sheets of stainless steel. Seam welding of materials of high conductivity is another instance where welding by electronic devices has proved of great advantage. In neither of these cases

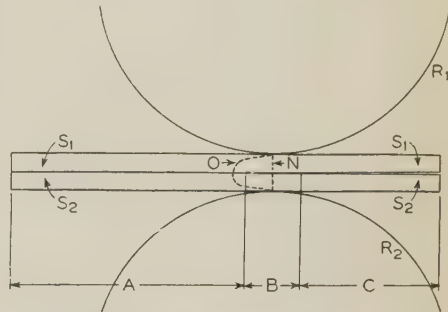
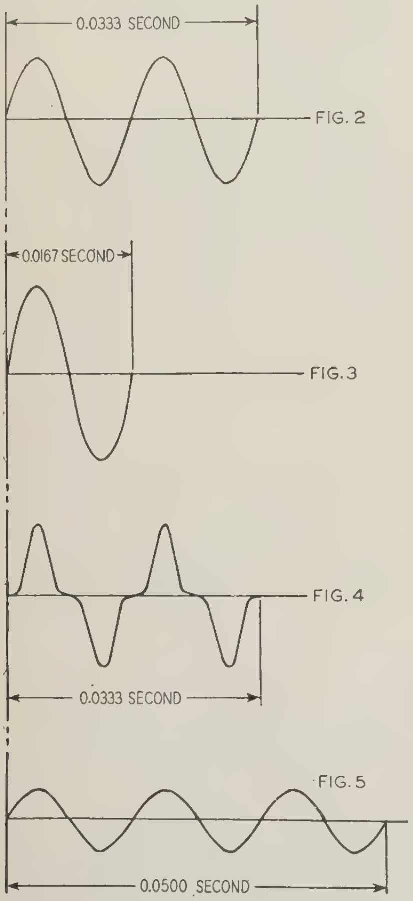


Fig. 1. Diagram illustrating welding of low resistance sheets by roller electrodes

were satisfactory results readily obtainable with mechanical switching devices. In considering the reasons for these superior results, it is usually assumed that the ability of electronic devices to govern exactly the total amount of energy in each weld over a very short period of time is the essential feature. This is probably true in connection with stainless steel, where this feature minimizes deterioration of the material in the welded area, especially on the outer surfaces of the sheets. However, I believe that in seam welding of low resistance materials, correct control of the rate of rise of the welding current is of equal importance if not greater than exact gauging of the energy.

Figure 1 of this discussion shows 2 sheets (S_1 and S_2) of low resistance material to be welded by the roller electrodes R_1 and R_2. It is assumed that the welding of the distance *A* is completed and a welding current is about to be sent through the area *B* to effect the next weld. It may further be assumed that there is in many cases a high resistance oxide film on the surface of the sheets, as indicated by the heavy line over the distances *B* and *C*. If the ohmic resistance alone is considered, it is likely that on account of the low resistivity of the material the current would essentially follow the path *O* instead of the path *N* as desired. If, however, inductance is present in addition to ohmic resistance, the higher inductance of the path *O* will force a greater portion of the current through the path *N*.

It is therefore evident that high inductance, and consequently a higher rate of rise in the welding current, may be essential to accomplish satisfactory seam welding with low resistance materials. Although it may be possible to produce equally satisfactory individual spot welds with currents as shown in figures 2 and 3 of this discussion, as-



Figs. 2–5. Welding current wave forms

suming that the total energy is the same in both cases, the current in figure 3, on account of the greater rate of rise in the welding current, may give much better results than that in figure 2 in the case of seam welding, because as pointed out a greater portion of the total energy will go through the spot to be welded. It is also likely that with even a smaller amount of total energy, the type of current wave shown in figure 4, which as stated in the paper can be readily obtained and exactly controlled by means of an electronic timing device, will give more satisfactory results than the current in figure 2, again for the reason that a greater portion of it is likely to go through the spot to be welded.

The magnetic properties of the material to be welded should also be of importance in connection with these phenomena. If the material to be welded has magnetic properties, it will, other conditions being equal, be much easier to accomplish seam welding without steep wave fronts because the path O will naturally have higher inductance than the path N.

Control of the steepness of the wave front may also be of advantage in controlling the size of the spot weld in the case of high resistance materials. It is well known that with high frequencies there is a so-called "skin" effect, tending to force the current toward the outer layers of the conductor. This is indicated by a number of current paths (N, P, and Q) in figure 6. However, if the material is of high resistance, most of the current will have more of a tendency

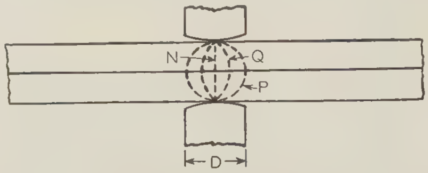


Fig. 6. Diagram illustrating welding of high resistance material

to follow the shortest path N with normal sine waves of standard 60 cycle frequency as indicated in figure 5. With higher frequencies, greater spreading of the current and a larger weld could be effected. Changing the frequency is, however, usually inconvenient, but equivalent results can be obtained with an electronic welder by means of a wave shape as indicated in figure 4. Here again the magnetic quality of the material to be welded may have appreciable influence upon the result because it influences the "skin" effect.

In practice it is customary to find the best adjustment by the cut-and-try method, but appreciation of the importance of the steepness of the current wave, as pointed out in this discussion, may be of assistance in arriving at the proper adjustment more quickly.

H. L. Palmer (nonmember): It is interesting to note that the author describes the use of a mechanical timer to control the power tubes on his line welder control. When using a motor driven interrupter it seems somewhat awkward to change a considerable number of slots in a disk or to put on a new disk. In order to make a large change it may even be necessary to change the gearing between the motor and the disk, and the interrupter must be gear driven in order to maintain synchronism. The welding cycle, or "time on" plus "time off," is confined to a definite number of combinations unless a complicated gear changing mechanism is used. In order to meet the exacting requirements of accurate firing points for the power tubes, this mechanical timer must be a precision device that may require considerable maintenance.

The author under "Description and Rating" states that one of the adjustments in the control box controls the point on the voltage wave at which the weld is initiated. The determination of the correct point of firing the first cycle of a multicycle spot can be determined only by observing the line current by means of an oscillograph. Therefore, the advisability of putting such a control in the hands of an operator seems doubtful unless he is provided with some means of checking his line current transient.

It would seem that such an adjustment which is a function of the particular welding machine and its secondary leads, and not the work, might better be at the main control panel and be changed only by a maintenance man with the necessary instruments. If the operator should get the firing point too far off from that providing minimum line current transient, excessive current surges and saturation of the welding transformer will result. In the case of high duty spot welding this will overheat the welding transformer by excessive exciting current in this saturated condition.

It would be interesting to know just how Stoddard expects the operator to know when this adjustment is correct.

A High Power Welding Rectifier

Discussion of a paper by Daniel Silverman and J. H. Cox published in the October 1934 issue, pages 1380–3, and presented for oral discussion at the electric welding session of the winter convention, New York, N. Y., January 23, 1935.

R. E. Hellmund: See pages 755–6.

High Velocity Streams in the Vacuum Arc

Authors' closing discussion of a paper published in the November 1934 issue, pages 1454–60, and presented for oral discussion at the electric welding session of the winter convention, New York, N. Y., January 23, 1935. Other discussion of this paper was published in the April 1935 issue, page 444.

E. C. Easton, F. B. Lucas, and **F. Creedy:** L. R. Ludwig has repeated the authors' warning against accepting some of the results of our work without further experimental confirmation.

All tests on the copper arc were conducted at the same time and with the same electrodes. Each point on the curves is the result of one test, but the distribution of successive observations between the 2 curves is quite random. There were, unfortunately, no measurements of arc drop. If this division into 2 curves is not due merely to experimental error, then there must be 2 conditions under which the copper arc may exist. Each of these conditions may be marked by a different velocity of the cathode stream, a different velocity distribution, or, as Ludwig points out, by different masses of the particles which make up the arc stream. The authors have stated in the paper that they themselves are not yet convinced of the existence of this condition of dual stability.

The authors do, however, accept the existence of an anode stream. We have reported the observations which cast doubt on the evidence. The most significant of these concerns the appearance on the vane of cadmium from the shielded electrode. This result, however, can have but little bearing on the tests on the tungsten anode. Here, with a copper cathode, no copper reached the vane. The force on the

vane must, therefore, have been due to the tungsten anode stream. Definite conclusions concerning the variation of velocity with current cannot be drawn from the scanty data at hand.

The occurrence of 2 curves in figure 11 is unexplained. This figure together with the other controversial features of the paper is presented in the hope that other investigators may be inspired to further experiments which will confirm or refute the relations which we have suggested.

Engineering Education Is Meeting the Challenge

H. W. Bibber, October 1934 issue, pages 1356–9

On the Schooling of Engineers

Alex Dow, December 1934 issue, pages 1589–91

Characteristics of a Group of Engineers

Thomas Spooner, December 1934 issue, pages 1571–6

Discussion of a group of papers presented for oral discussion at the session on education at the winter convention, New York, N. Y., January 22, 1935.

P. L. Alger (General Electric Co., Schenectady, N. Y.): In my opinion, these papers form one of the most interesting and thought provoking series ever presented before the Institute. They are encouraging because they show progress is being made in the application of engineering methods to the development of human talents, and they are especially interesting because they reveal the latent possibilities in the development of the social as well as the technical talents of the engineer. The papers constitute an inspiration to all of us to contribute what we can to the further development of engineering education.

An aspect of this subject which interests me particularly is the measurement of the inherent qualities most helpful in attaining engineering success. For success in any field, of course, it is necessary to have energy, courage, and especially initiative, which imply willingness to assume and carry responsibility. Also, the faculty of judgment, or making wise decisions, is essential.

I believe, however, that technical imagination is the one quality which is outstanding in importance for success in engineering as distinguished from other lines. By technical imagination I mean the ability to so observe a particular diagram, object, or machine that its fundamentals, which are invisible to the average person, come to light. Just as the skeleton of a patient is clear in the mind's eye of a surgeon, despite the interposition of clothing, so imagination enables the engineer to see in his mind the lines of flow of the invisible air, or magnetic flux, or electrons, and to truly understand the behavior of the thing observed. This same faculty immediately brings to mind a whole series of pertinent questions whenever any object is critically observed. Anybody seeing a skeleton with half the bones missing would be moved to inquire for them. The unknown principles of any mechanism are equally obvious to the engineering mind.

With such imaginative ability, an urge to immediate action is self-produced, and a foundation for engineering success is made available. I, therefore, believe that some measurement of this faculty of technical imagination, or curiosity, or call it what you will, should be included in every test to select engineering talent.

A second quality, emphasized by Spooner, and which I think has grown much in importance in recent years, is that of co-operative ability, which really means human understanding, or plain sympathy. The tremendous development of science and the growth of large industrial organizations depend upon, and in turn require, increased specialization. In any large project, therefore, numerous individuals must contribute, and the progress made is vitally dependent on the degree of co-operation secured. The question then arises if co-operative ability can be measured.

Co-operation is secured when and only when every individual in a laboratory can draw as often and as deeply on the knowledge of every other member of the staff as he desires, without friction and with the minimum of effort. To co-operate most effectively, it is absolutely necessary that the individuals not merely understand each other, but that they trust each other. Some people have the faculty of appearing to be co-conscious of the ideas and feelings of their fellows, or themselves to receive the emotions and ideas of others with extraordinary facility. Intelligent sympathy of this sort appears to me essential if co-operation is to be secured, and this quality, therefore, is of great importance for success in modern engineering work.

In independent work and in small organizations, the faculty of aggressiveness seems of greater importance, but in larger organizations that of co-operative ability seems predominant, as this ability provides the cement that holds together the numerous human elements in the working group.

I like to think of engineers in industry as separate stones forming a masonry structure. To get the best results, the problem is to build the complete structure with the greatest strength to resist forces applied in any direction. The only cement that can be used is the co-operative ability inherent in the individuals. At best, however, this cement is weak, so that the strongest structure results when a few large stones of interlocking shapes are used, rather than a large number of small round stones. In the same way, it is important to use 2 abilities possessed by a single engineer, rather than to rely on 2 engineers with single abilities. The best engineering organization will result when the ablest individuals are allowed to exercise all their abilities to the fullest degree, and the best co-operators are used as connecting links between groups.

My conclusions are that engineering colleges should, first, select the ablest students they can secure, and then develop their individualities, especially their technical abilities, along the broadest possible lines in the time allowed, including some cultural training. Colleges should make every ability of a student take root and sprout, but should not develop any specific ability very far. After receiving these men, industry should first cultivate the specific abilities most suited to the work to be done, and later the co-operative and administrative abilities that develop with experience. Furthermore, every industry should continually tailor its jobs to fit the growth of the individuals available, rather than try to cut any man down to fit a prescribed job.

Alan Howard (General Electric Co., Schenectady, N. Y.): I have been very much interested in the ideas expressed in these papers and I am glad to see the co-operation and mutual understanding between the schools and industry continue to be increased materially. I am particularly interested in the relation of education to industry since for the last several years part of my work has been in connection with the advanced course in engineering of the General Electric Company. I have thus been in educational work and industry at the same time and so have had an unusual opportunity to see several sides of the picture.

In this work I have seen many exceptionally capable men get their start in industry, and based on this experience there is one important aspect of the training of men to which I would like to call attention. It is an aspect which is implied in nearly all papers on education but it is not pointed out as definitely or as often as is desirable. It is a point which many men coming into industry do not appreciate.

Success in industry is synonymous with accomplishment. Those men get ahead fastest and furthest and are of the most value to society and industry who achieve the most—obtain results—*get things done.* Many graduates have the idea that knowledge, the ability to co-operate, the willingness to work hard are fundamental and that they will be advanced primarily because of qualities of this type. This is not true. These qualities are very desirable, but none of them is basic; advancement is necessarily based almost entirely upon achievement. That is, if a man can make real accomplishments, he will be successful, even though he is materially lacking in many of the factors usually associated with success.

Many engineering graduates have had the habit of studying and working with the primary objective of increasing their store of knowledge for so long that when they arrive in industry they naturally continue in this way. Their prime motive appears to be to gain information and experience rather than to be of service. If questioned directly, they generally state that they believe accomplishment to be fundamental, but their actions and attitudes all too often indicate that they do not realize the importance of *getting things done;* of arriving

at definite and useful results. They do not have the habit of achievement.

The responsibility for the development of this habit of achievement doubtless rests largely with industry, but I believe the colleges can, and that many do, help materially in this respect by continually emphasizing the importance of applying knowledge and ability toward definite ends, and by arranging courses and activities so that students get as much experience in such application as possible.

The specific idea I wish to emphasize is that in addition to being educated in knowledge and co-operation, it is extremely valuable and helpful to the college man to be educated in accomplishment, to have formed the habit of achievement, as well as the habit of study, to be experienced in using his good qualities in addition to merely possessing them. Those graduates who do have the habit of achievement fit more easily into industry and progress more rapidly than those who have to learn this habit after they arrive.

H. W. Bibber (Ohio State University, Columbus): It is most interesting to see that Alex Dow's opinion—that there should be an increased emphasis on the arts of expression, economics, and history in our engineering courses—coincides with that of a fairly large number of Ohio State Engineering College alumni whom we have approached on this question of curriculum content.

Dow's suggestion that a student would do well to go into the field for a couple of years and thereafter come back to school for further work strikes a responsive chord in the heart of every engineering teacher. As a result of the depression there have been many students who have done this at my institution in the last 3 years, with definitely more value to themselves than is often the case with those who take a fifth year immediately following the 4 year program. But in normal times or for those recent graduates who have secured employment, how difficult it will be for them to cut loose from the work in the field where they have been fortunate in securing employment! Many in the course of a year or 2 in the field get married. This makes their return to school more of a problem, but not, of course, impossible. The one thing that would help in this further postgraduate education of junior engineers is to have employers promise re-employment at an increased salary on the conclusion of a satisfactory period of postgraduate study in some university or college. One would think that the self-interest of employers of engineers would lead them to do this. Up to this time I have heard, however, of only a few cases where this apparently promising measure has been taken.

Thomas Spooner in his paper has given the added weight of definite quantitative evidence to the contention set forth in my own paper, that the school should be more a part of real life. Quite as he states, this is not in line with the mass production of engineers, or the effort to improve the "efficiency of instruction" by raising the number of students taught per instructor.

At Ohio State we make use of the Student Branch of the A.I.E.E. to present talks by men from industry to emphasize the importance of personality factors. Each year I make it a practice to have several conferences with men who are failing in their course work, and in the course of these I have discovered several interesting things. To quote just 2 cases which are typical will perhaps show the possibilities of an early study of personality traits. One student who was failing the class work in a-c machinery lacked interest and appeared indifferent and dissatisfied, but the sketches and diagrams of his laboratory reports were excellent. It developed that his real interest was in art, and a transfer to the fine arts department has made him a successful student and revolutionized his attitude, with I think, ultimately far greater promise of professional success. The second case is a student whose work in d-c machine theory was unsatisfactory, and whose ability to grasp technical material was apparently very slight. After considerable questioning the reply came from him that he was taking the electrical engineering course because he wanted to work in a radio station, but not, it developed, in an electrical engineering capacity. He was absolutely in the wrong groove. A transfer to the college of arts where a specially devised curriculum has been laid out for him has turned him from an academic failure to a success, and has worked wonders in altering his mental outlook. One cannot, of course, predict what progress this student will make in actual employment with some radio station, but a fair estimate would place his success much higher there than it ever would have been in professional electrical engineering.

Mention has been made of the fact that the broadening studies included in an engineering curriculum may need to be conceived in a different manner than has been traditional. I quite agree. Psychology, as I view it personally, is a science based upon the more fundamental sciences of life, such as biology, zoology, bacteriology, etc., so that in this sense it is a science dealing directly with factual matter and therefore analogous to the physical sciences. Perhaps I should have spoken of the social studies rather than social sciences, as many engineers and perhaps biologists would not consider the use of the "science" term justified. In economics and business organization there is considerable lack of agreement as to the conclusions to be drawn from data derived from observations of the same phenomena. There is a large amount of opinion carrying a heavy charge of emotionalism. The traditionalists and the verbalists may well confuse engineering students, and social studies taught in the traditional way may contribute but little to the development of the engineering student. I recognize all this, and therefore the newer type of instruction in the social studies is implied in all I have said.

Ernst Weber (Brooklyn Polytechnic Institute, Brooklyn, N. Y.): Bibber tries to incorporate social sciences into the engineering curriculum and a feasible method to do this is described under the heading on "Make-Up of a Modern Engineering Course." It seems evident that the strength of engineering education is the development of problem solving ability. However, this faculty cannot be applied to social sciences. "Problem solving" implies that one knows the problem; but what definite knowledge do we have about a social problem? There are no numerical assumptions possible. It is not even possible to agree upon the proper statement of a social problem. Likewise, whether a solution is correct or not cannot be checked in social science, as the factors in the experiment cannot be controlled. Social leaders must be persons who have long vision, an intuitive grasp of the situation, and ability to think logically; not men trained to solve specific problems. One cannot mix training in engineering and the arts, without weakening either or both. Both curricula appeal to different faculties of the human mind, and only exceptional minds will follow into both fields.

In reference to "real life" it would be necessary first to define what is meant by real life. It does not seem that secondary education is succeeding particularly well in the development of strong personalities. Life in general requires continuous readjustment of the mind. This faculty of adjustment must, therefore, be developed in children, and it is just the lack of well organized training of the mind that makes the freshman the perpetual problem in the college.

It cannot be the aim of any university or college education to prepare men for special jobs. The aim and the indisputable responsibility of the institutes of higher education are to create a large enough reservoir of the nation's most treasured youth to supply any walk of life with "men" and not with "workers." In this connection it is most interesting to note that the proposals in Dow's paper are entirely separated from any specific education for special jobs and emphasize the need for a general fundamental training in preference to any expert training.

The method used by Spooner to study the requirements of research workers to succeed in their special field of choice does not seem applicable in principle. In order to yield proper results, the method must employ large numbers of investigations. How many individuals are represented in a graph? It cannot be permissible to discuss any of the graphs in the manner the author does, as judgment on personality factors is extremely difficult and depends upon the person judging. As a matter of fact, all the graphs look alike and it is very difficult to conceive how discussion could bring out fundamental differences. There is too much tendency on the part of the applied psychologist to consider human beings as more or less mental machines, to be classified, stamped, and numbered. A change in attitude is rapidly approaching and rightly so.

As education is a part of the vast field of social sciences it is evident that no single correct solution for the problem of engineering education can be found. All we can do is join in a concerted effort to attain as high a perfection as is humanly possible of the complex and diversified functions of the institutes of higher education. May I present a few points which seem to me worthy of national consideration:

First, there is a definite need for special preparatory schools for college or university study. At present the first year of college study is usually spent to awaken the student's ability of free and independent thought. Tremendous harm is done by high school

methods to many youthful minds who never can recapture their mental freedom from textbooks.

Second, elementary as well as secondary education should be co-ordinated in a national plan to develop the character of the individual and a broad knowledge of the principles of pure science as well as the social sciences. Present educational conditions lack in general the rather rigid personality training and training of the mind, which can be obtained only by continued exercise in principles and not by memorizing of rules.

Third, instead of the "horizontal" structure of engineering education which Morrow proposed and Bibber again outlined in his paper as 2 parallel branches of engineering training, the "vertical" structure seems preferable. The bachelor's degree should indicate general training with emphasis on particular, broad engineering fields. Expert specialization should take place in additional postgraduate courses so that the master's degree would be an indication of special training.

Fourth, social science courses are in general not yet in such shape that they could be satisfactorily included in an undergraduate engineering program. A beginning may be made but not with the purpose to teach how to administer or do executive work. Particular stress may be laid upon the field of production and consumption economics.

Fifth, the idealistic side of higher education must be stressed; learning in order to know should predominate over learning in order to be worth more in dollars. It is rather detrimental to higher education if it is reduced to a business point of view.

Sixth, in a time when the government goes very far to secure social financial help for the many unemployed men should there not also be more done for social mental promotion and help? A comprehensive plan for national organization of highest education, in co-operation with the existing societies, should prove a fundamental step toward unification and the encouragement of highest standards.

Engineering Education Is Meeting the Challenge

Discussion and author's closure of a paper by H. W. Bibber published in the October 1934 issue, pages 1356–9, and presented for oral discussion at the education session of the winter convention, New York, N. Y., January 22, 1935.

Albrecht Naeter (Oklahoma Agricultural and Mechanical College, Stillwater): In his address at the Hot Springs convention last summer William McClellan emphasized the unity of the engineering profession. He suggested that the great founder societies, among others, should call upon the colleges to start out the graduates of engineering schools with the idea that they belong to one profession by giving them a degree, for example, of bachelor of engineering.

The title of Bibber's paper is highly suggestive and its content admits the possibility of various types of solutions in meeting the challenge of changing society.

A new course in general engineering has been organized at Oklahoma Agricultural and Mechanical College. It will not displace any of the present engineering curricula but is available to provide a broader training than is possible under any of the specialized engineering programs of study.

This new general engineering course of study includes at least $^3/_4$ of the standard courses covered in civil, electrical, industrial, and mechanical engineering, each of which is set up in accordance with the recommendations of the Society for the Promotion of Engineering Education. In effect, it is a composite course of the technical engineering elements of general civil engineering, power electrical engineering, industrial engineering, and general mechanical engineering, set up on the common base of rigorous training in basic physics, chemistry, mathematics, and mechanics. There is the usual amount of English, economics, accounting, etc., and provision is made for a limited number of electives. It is recommended that students choose cultural subjects for electives, even though they may choose scientific or technical subjects. Upon completion of the work, a bachelor of science in engineering degree will be granted.

When he has completed this new course, the graduate can seek employment in a wide range of fields. He will have sufficient training to handle the work that he is likely to be called upon to do. After he has oriented himself in industry, he can complete in one additional year of study the curriculum leading to the standard qualified bachelor of science degree in civil, electrical, industrial, or mechanical engineering.

H. W. Bibber: It is interesting that the Oklahoma Agricultural and Mechanical College has instituted in part the type of program which I was describing. Naeter does not specify the method of administration of the new course, but I assume that it must be well supervised, have high standards, and be not at all a place of last resort or haven for "lame ducks" who want an engineering degree for some reason, but whose intellectual qualifications, in the opinion of most people who come in contact with them, do not warrant it.

P. L. Alger's discussion is most stimulating. What is said by an enginer who is so eminent is very much worth noting. I take it as a postulate that the colleges and universities cannot develop anything in an individual unless a capacity for the talent or skill exists. They can only shape their program and so arrange the execution of their work that the energy, courage, and initiative of the student may be directed in productive avenues of expression. To me this means the necessity of a flexible program and the services of instructors on the staff of the educational institutions who are not dogmatic about hyoptheses or other unproven propositions. One of the disappointments of many college teachers, I suspect, is the lack of ability or even willingness to carry responsibility on the part of most students from ordinary high schools. The type of test to be devised to measure the technical imagination possessed by a student is to me a stimulating problem for research, and I shall be much interested in seeing what can be done to discover this quality at various stages of the careers of our students, preferably as early as possible. Work on experiments and other projects in groups certainly starts a student on the road to co-operative endeavor. Unfortunately, most of the testing of students' qualities which is now carried on in universities consists in measuring his individualistic capacities rather than his co-operative ability. It may very easily come about at the present time that a student with considerable personal mental endowment may secure very high grades on his own performance as an individual and yet be lacking in much of a co-operative gift or spirit. From conversation with representatives of employers who come to our institution, I gather, however, that this is a factor the importance of which they are quite aware, and that they try to estimate the student's capacity in this direction when interviewing him.

Alan Howard's comments lead me to say that the increasing use of the project method should make the graduate of engineering courses in the future more accustomed to definite achievement. Each time a student solves a problem he achieves a goal which has been set for him. It is true that there is a lack of reality to school problems, try as one may to make them vital, because the penalties and rewards of industry are not present in the school situation. Most college teachers would like to incorporate the spirit of reality and achievement in a student's program much more than it exists at present.

While Ernst Weber appears to differ with me in many of the bold statements in my paper, yet it may well be a question of the language or definition of terms alone which gives this appearance. Furthermore, I do not claim that social problems can be solved with the same dispatch or preciseness as physical problems. It is true that numerical measurements in the social science field are at present imperfect or entirely lacking in some parts of this field. To me this indicates that we may now be at an early stage of progress, rather than showing that there never will be any possibility of extensive measurements in the social field. It seems to me that the social sciences are now at the point of relative development at which the physical sciences were a century or 2 ago, but this does not mean that the metrically minded man is not needed in the social science field. Quite the contrary!

To exclude social studies from the undergraduate engineering program because they are not at present as metrical or well organized as the physical sciences is to disregard the type of life which the student will later live.

I agree that a mixture of arts and engineering in one course would be ill advised, but I believe that separate courses in arts and technology may be given to a student in one curriculum during his college years. In actual life situations, an engineer concerns himself with technology from 6 to 8 hours a day, the remainder of his waking hours being largely devoted to problems of social and individual living. I do not claim that many men will become eminent in both engineering and the humanities or arts. I am concerned with an intelligent appreciation or understanding of society, and I believe that an engineer of average intelligence can comprehend significant aspects of this field if reasonably stimulated and guided. K. T. Compton recently remarked, "the increasing necessity for organized co-operation with economic and social controls, whether along the lines of the 'new deal' or some different basis, creates an urgent demand for men with engineering training and a broad conception of relative social values and economic processes. It is desirable to develop a co-operative approach to economic problems by the engineer and the economist, in somewhat the same way as has proved so fruitful in the co-operation of the engineer with the physicist, the mathematician, the chemist, and the biologist."

My references to the newer type of secondary education seem to have been misinterpreted by Weber. It is precisely because of the lack of ability for independent study that efforts are now being made to reform the secondary schools in the United States. As I understand it, the effect of the newer plan is to encourage initiative and self-development on the part of the students and to divorce them from the rigid discipline of a fixed routine of study, substituting therefor a flexible discipline of self-measurement against some objective scale of values. It is precisely because freshmen have no self-discipline that they have been a continuous problem in our engineering schools. At my own institution we have an experimental high school. The new building for this work was completed recently and I was interested to note, carved in stone over an entrance door the words, "Prize the Doubt." From many conversations with the teachers and administrators of this experimental secondary school, I gather that this is characteristic of progressive education. What Weber lists as points 1 and 2 in his suggestions for national consideration are exactly in line with what I understand to be the objectives of present secondary school reform. In his comments as to the "vertical" form of engineering training, I agree that the master's degree may often indicate specialization. My suggestion of "honors courses" is based on the possibility of recognizing and taking advantage of individual differences in students. In other words, a gifted student may master and be able to use effectively in 4 years as many engineering principles as a less well endowed student in 5 years or more.

Characteristics of a Group of Engineers

Author's closing discussion of a paper published in the December 1934 issue, pages 1571–6, and presented for oral discussion at the education session of the winter convention, New York, N. Y., January 22, 1935.

Thomas Spooner (Westinghouse Elec. and Mfg. Co., E. Pittsburgh, Pa.): "Technical imagination," as defined by P. L. Alger, is undoubtedly a very valuable trait and one which could well have been included in figure 2 of my paper. He states that it "should be included in every test to select engineering talent." I hope that some time he will amplify this suggestion and tell how best to determine to what extent this trait is present in an individual.

I am glad to note that he emphasizes the desirability of co-operative ability, especially in a large organization. In this connection it is interesting to point out, as shown by figures 1 and 3 of the paper, that lack of co-operative ability appeared as 13 per cent for those men released and was zero for those retained.

Alan Howard's expression "habit of achievement" is a particularly happy one. However, for the young engineer, it needs, perhaps, a little clarification. To the student, achievement may mean simply a correct solution of an assigned problem. To the design engineer, it may often mean much the same thing. To the development and particularly the research engineer, it usually means much more than this. Unless the solution was urgently desired by some designer or commercial department, the research man is faced with the necessity of selling his idea so effectively that it will result in manufacturing and sales activity. This may require his most persuasive efforts and will bring into play his social and personality traits. He cannot simply say of his development: "Here it is. It is good. Take it or leave it." He may have to work for months or years to convince others that it is worth while, and without this effort there will be little real achievement and no chance to acquire the habit of achievement. Even the designer, who has been set a specific problem, must convince others that his solution is the best one, since most design is largely a matter of compromise.

Howard is quite right. It is an engineer's record of accomplishment rather than his reputation for knowledge which counts most with his superiors.

Ernst Weber states that the graphs of my paper "look alike and it is very difficult to conceive how discussion could bring out fundamental differences." They do look alike, of course, but quantitatively, they are quite different. Figures 1 and 3 only can be compared directly. An analysis shows that the faults of those retained amount to only 46.5 per cent of those released. This seems like a significant difference. Individual items are even more important as, for instance, the one of co-operative ability mentioned above, where this lack is 13 per cent for one group and zero for the other.

Weber intimates that valid conclusions cannot be drawn from the graphs because "judgment on personality factors is extremely difficult and depends upon the person judging." We grant the difficulty and variability, but an executive's or personnel expert's opinion must be reasonably reliable for it is chiefly on the basis of such judgment that successful organizations are built up. I believe that Weber must grant that after a group of men has been associated together closely for years, each man has a fairly accurate knowledge of the strong and weak points of his individual co-workers, with respect to both technical and temperamental traits. The difficulty lies rather in balancing the strong points against the weaknesses and deciding on a man's value on the basis of all of his qualities when it comes to a question of promotion or release.

I wish to comment on Weber's statement in the next to last paragraph of his discussion; namely, that "the idealistic side of higher education must be stressed; learning in order to know should predominate over learning in order to be worth more in dollars." It is quite right and eminently desirable that a certain number of able scientists should be seeking knowledge for its own sake without any ulterior motive, but the number should of necessity be rather limited. We are discussing engineering and not scientific education. Most students study engineering because they believe that for them it will lead to the pleasantest method of earning a living. If they are tempermentally and mentally suited to become engineers, this aim is a reasonable and just one. I believe that the primary aim of an engineering education is to teach one to earn a living in a manner which will be useful to society and to accomplish this with a reasonable degree of success requires much more than the mere acquisition of technical knowledge. Human relationships are quite as important as technical ability.

On the Schooling of Engineers

Discussion of a paper by Alex Dow published in the December 1934 issue, pages 1589–91, and presented for oral discussion at the education session of the winter convention, New York, N. Y., January 22, 1935.

H. D. James (Westinghouse Elec. and Mfg. Co., Detroit, Mich.): I read this paper with considerable interest, particularly as I know the author's background, which makes his statements of unusual value to me.

We are apt to consider our graduation from college as the end of systematic study; we hope that we are well equipped for our life work. If we did conscientious work at college we have laid a valuable foundation, but have acquired only a limited knowledge and training. We instinctively study the problems presented by our immediate job, and for a time they may absorb most of our energy. After we have mastered them we should plan for broader study.

The occasional reading of magazine articles on a wide variety of subjects gives us a smattering of information that is useful in conversation but adds little to our real education. We should select one or two definite subjects and study them in a systematic manner, selecting other subjects only after we have acquired a good understanding of the first ones. Each year we should try to add something definite to our education.

Only part of our studies should be on engineering subjects; we should try to improve our own efficiency in writing and speaking and business methods, in the preparation and presentation of reports, and in learning how to intelligently enjoy ourselves. One or 2 hobbies will help us to relax.

Some of our efforts should help us to understand the "human machines" with whom we must co-operate and whom we may later have to lead. As the author points out, this is not an exact science, but we can understand persons through history which tells us how people have acted in the past; psychology gives us some idea of their mental processes, and economics helps us to think more clearly on business problems. We cannot get all of these things in 4 short years at college, and, besides, information on these subjects is increasing each year so that we must continue to study them. Knowledge is "dynamic," not "static."

As we grow older, the things that count most are character, judgment, a human attitude toward and understanding of others, and that subtle quality that we call personality. To develop these we must acquire a broad knowledge of human nature and of spiritual values. We must develop a philosophy of life that is sane and that will help us through our difficulties and give us bal-

ance when we are successful. These things do not fit into an exact science nor can they be expressed by a mathematical formula. They come from systematic study and careful thinking.

Dow says that men do not carry nameplate ratings; he knows that each person has a different individuality. If we are to be successful in leadership we must understand each individual that we direct or work with; this knowledge is a composite of our own training and experience. We cannot hope to inspire a higher performance in others than that which we are capable of rendering ourselves. The real leader is the one who sets an example.

Low Pressure Gaseous Discharge Lamps

Discussion of a paper by Saul Dushman published in the August 1934 issue, pages 1204–12, and in the September 1934 issue, pages 1283–96, and presented for oral discussion at the illumination session of the winter convention, New York, N. Y., January 23, 1935.

A. C. Downes (nonmember): There are given in table I of the paper luminous efficiencies of various sources of light. In this table appear some data on a white flaming arc. It is not stated whether this arc is on direct or alternating current, and against the data for this arc is the following notation, "assuming that most of the light is due to the carbon crater, the temperature of which corresponds to that of a black body at from 4,000 degrees to 5,000 degrees Kelvin." In flame arcs the craters on the electrodes are sources of only a very small part of the energy emitted and the major portion of the light comes from the luminous flame between the carbons.

In this table the white flaming arc is shown to have an optimum luminous efficiency, L_0, of 220 lumens per watt. We have calculated this value from measurements on a white flame arc burning at 40 amperes and 37.5 volts (Bowditch, Joy, and Downes, Society of Motion Picture Engineers *Journal*, volume 22, page 58) and find the value of L_0 to be approximately 216 lumens per watt, a very close agreement with the value in Dushman's table.

The specific luminous efficiency L_s for this white flame arc is shown to be from 27 to 45 lumens per watt in the same table. Actual measurements in our laboratory have shown that a white flame arc operating under the above conditions, that is, 40 amperes and 37.5 volts, has a specific luminous efficiency of 79 lumens per arc watt.

In the table this arc is shown to have an energy utilization ratio 100η of from 12 to 20. Actual energy distribution curves of such an arc have shown that 36.6 per cent of its energy lies in the visible portion of the spectrum, between 4,000 and 7,000 Ångström units, and the value calculated from $L_0 = 216$ lumens per watt gives this same value for the energy utilization ratio.

Operating the same type carbons on an alternating current circuit with a number of arcs in series or a single arc operated on a transformer under the same current and voltage conditions will show a specific luminous efficiency of 70 to 75 lumens per watt and approximately the same energy utilization ratio.

Induction Motor Locked Saturation Curves

Discussion of a paper by H. M. Norman published in the April 1934 issue, pages 536–41, and presented for oral discussion at the induction motor session of the winter convention, New York, N. Y., January 24, 1935.

S. F. Henderson (nonmember): This paper is of considerable value to the motor designer, and when its merits are fully appreciated will receive wide use. The corrections given here have been applied to a number of designs and the calculated starting currents checked test results within 5 per cent.

The most outstanding example involved an English design of a wound rotor motor having a small air gap and overhanging teeth of light section. The results were:

	Starting Current, Amperes	Max. Torque Per Cent
Calculation without correction	160	145
Test values	260	225
Calculation with correction	248	215

The importance of making corrections for saturation is evident in a design of this type and it is interesting to note that the formulas in this paper gave results with good accuracy.

Since the corrections are in the form of reductions in slot and zigzag reactances, I believe the author could include to advantage formulas for the various reactances of a motor. Each design engineer has his own set of formulas and a paper dealing with motor reactance calculations should be of considerable interest and result in much interesting discussion.

Efficiency Tests of Induction Machines

Discussion and authors' closure of a paper by C. C. Leader and F. D. Phillips published in the December 1934 issue, pages 1628–32, and presented for oral discussion at the induction motor session of the winter convention, New York, N. Y., January 24, 1935.

S. L. Henderson (Westinghouse Elec. and Mfg. Co., E. Pittsburgh, Pa.): This paper shows how much more difficult it is to determine by test the load losses of an induction motor than the load losses of a synchronous machine. The paper is confined to a discussion of 3 different types of test, i. e.: (1) test by dynamometer, (2) test by loading on a duplicate machine, and (3) segregated loss method. The first 2 tests are primarily input-output tests and as in any such test are subject to the same difficulties and large expense attendant on obtaining reasonably accurate results. This point is well brought out in the paper. These tests, at least at present, can be made only on motors of not over 200 horsepower because of the limitations of equipment. This leaves then only the third method, the segregated loss method, for the larger motors. There is a fourth method, the calorimetric method mentioned but not discussed by the authors, which has possibilities at least in some cases.

The segregated loss method for determining the efficiency is attractive because the cost of the tests is less and the component losses can be obtained with greater accuracy. The only element in doubt at present is the accuracy with which the load loss may be obtained. On synchronous machines the load loss is obtained by driving the machine excited with direct current and with its terminals short-circuited. The load loss is found by subtracting the friction windage, driving motor losses, and the stator copper loss from the driving motor input. The accuracy of this test has been demonstrated by input-output tests and by calorimetric tests.

It is proposed in the induction motor test code, now being drawn up, to use this same test for induction machines. However certain difficulties arise when attempting to apply this method to induction motors, and further there has not been a sufficient number of confirming tests made to check the accuracy of the method when applied to induction machines.

The application of the method presents no difficulties on wound rotor motors and the test is conducted in the same manner as on a synchronous machine; one member is excited with direct current, the other member is short-circuited and the rotor driven at synchronous speed. The difficulty arises when applying the method to a squirrel cage motor. In this case the stator must be excited by direct current, but the rotor resistance and current cannot be measured to permit the calculation of the copper loss in the rotor.

A number of suggestions have been made to overcome this difficulty. The one in the paper is to obtain the rotor loss from a brake test at standstill and it would be interesting to know what the authors think about the accuracy of this test. A second method proposed by E. H. Linckle is to drive the motor at various speeds at constant excitation and plot loss against speed. The intersection of this curve with the ordinate through zero speed would give the rotor copper loss. The copper loss found in this manner is too low and the load loss too high. A third method would be to measure the slip at some load and from the slip calculate the rotor I^2R loss for this load. The copper loss at any other load will be proportional to the ratio of the square of the stator currents corrected for the magnetizing current. Fortunately it will probably always be possible to get a slip reading on load on a squirrel cage motor as seldom do these motors exceed 1,000 horsepower.

As for the accuracy of this short-circuit method for determining load loss, only a small amount of data and that only on small

machines has been presented. Linckle found in his work that on a wound rotor motor only half of the loss so measured equaled the load loss and on squirrel cage motors all the loss found on the short-circuit tests was equal to the load loss. The Westinghouse company has checked this method on one large motor.

A 200-horsepower, 700-rpm squirrel cage motor was found to have a load loss of 1.15 per cent from the short-circuit test but only 0.70 per cent from the dynamometer test. This dynamometer test was made according to modification of method *a* given in the paper. In other words, this one test shows the loss as obtained by the dynamometer as 60 per cent of the loss from the short-circuit test.

Short-circuit tests have been taken on 6 other motors ranging in size from 200 to 1,250 horsepower, both squirrel cage and wound rotor. The load loss varied from 0.9 to 2.5 per cent. There was not time, however, to check these motors by either a dynamometer or pump back test.

What is needed in order to approve the proposed test code on induction motors is more evidence as to the accuracy of the short-circuit test.

F. E. Harrell (Reliance Electric and Engineering Co., Cleveland, Ohio): The authors of this paper have indeed performed a service in pointing out the particular considerations in connection with the 5 methods of measuring efficiency of induction machines.

Table V in this paper, showing a comparison of results of the tests of various motors by the 3 methods most recommended, is of particular interest. Noting that the variations among the different methods of testing the same motor give results from checking exactly up to a variation of one per cent is a very much more favorable picture, certainly, than could be anticipated from the average testing laboratory, not to mention the average commercial test floor. These results are a tribute to the state of perfection and degree of training of the personnel conducting these tests and should give us all a worthy goal.

In connection with the proposed test code for polyphase induction machines, there are 2 items which, in the light of experience with inspectors from various governmental departments, bear emphasizing. First, in the so-called separation of loss method, the temperature of reference for stator and rotor I^2R loss is taken as 25 degrees centigrade plus the actual temperature rise, or not to exceed 65 degrees centigrade on an open motor as compared with 75 degrees centigrade previously established in the A.S.A. and A.I.E.E. existing standards. This is certainly a step in the right direction and should bear sufficient emphasis to register with these inspection departments.

Second, the matter of insulation resistance in the test code is covered by the conventionally accepted formula which makes acceptable less than half a megohm for a 440 volt induction motor. Where, from the standpoint of danger of breakdown, one megohm would seem to be a reasonable figure, there are repeatedly instances where inspection departments are insistent on maintaining values after abnormal tests of from 10 to 20 megohms, thus introducing needless cost and difficulty. It might be of interest to note in this connection that one large industrial plant whose surrounding conditions are extremely unfavorable to the average standard motor insulation regularly employs the megger to determine the condition of the motor insulation. The regular routine inspections are conducted at stated intervals, noting the insulation resistance. Motors are permitted to remain in service without unusual attention or further inspection beyond these regular periodic visits, until the insulation resistance drops below 50,000 ohms on 220 volt motors. The exact value below 50,000 ohms determines whether or not a motor is permitted to remain in service until the following week end or whether it is to be slated for immediate replacement.

C. E. Peck (Westinghouse Elec. and Mfg. Co., E. Pittsburgh, Pa.): The calorimeter method of obtaining the load losses of an induction motor has the following advantages:

1. The total losses are measured directly instead of being determined by the difference of 2 large quantities as in the dynamometer method.
2. The accuracy of determination depends on relatively few quantities compared to the other methods, namely: (a) measurement of temperature rise of the air directly as a difference between ingoing and outgoing air; (b) measurement of speed; (c) measurement of power input. All 3 of the quantities can be measured with commonly used test equipment. From the writer's experience the total losses of the motor can be measured with accuracy within $1^1/_2$ per cent.
3. The motor may be tested directly with the equipment it is intended to drive.
4. The method is more adaptable to all sizes of motors.

The method of carrying out the test involves the following:

1. The total no load losses of the motor are obtained in the conventional way.
2. A temperature run is performed on the motor under no load conditions. A stack is built around the motor in such a way that the temperature rise of the air passing through the motor can be measured accurately by means of thermocouples connected in differential series. Figure 1 of this discussion shows a motor under test with stack in place. From these data the volume of air passing through the motor can be found. The volume will be a constant for subsequent load conditions, and depends only upon the speed at which the motor is operated. The purpose of the no load run is to obtain a calibration of the air volume at a given speed.
3. A temperature run is performed under load and the temperature rise of the air is again measured, together with motor input. The total loss under the load condition can be determined from the air temperature under the load and the air volume obtained from the no load run.

T. H. Morgan and **V. Siegfried** (Worcester Polytechnic Institute, Worcester, Mass.): The importance of including the stray load loss in the determination of induction machine efficiencies is rapidly being recognized, as is also the need for more reliable methods of measuring this loss. The tests described in this paper indicate an improvement in the technique of segregating losses as measured by input-output methods under actual conditions of loading. The stray load loss, however, still appears only as a residual after subtraction of the output and known losses from the input. The measurement with d-c excitation is made under conditions quite different from those actually existing under load and consequently is at best only an indication rather than an accurate measurement of the stray load loss. The results of the tests by the authors would seem to bear out this contention. In the tabulated values, good agreement in the determined stray load loss is shown by the input-output test results, but there is a

Fig. 1. Motor under test surrounded by stack for measuring air temperature rise

considerable difference between these values and the stray load loss determined by the "direct method."

The pump back methods used with similar machines furnish the surest means of determining this loss under actual conditions of load, but distinction must be made between tests in which the machines are directly coupled mechanically and those in which the electrical supply is common to both machines. Where the rotors are directly coupled, the excitation of each machine is at a different frequency, and measurements of input and output must be made separately. The determination of the stray load loss in this case results from the subtraction of one relatively large quantity from another of similar magnitude, involving the inaccuracies common to all input-output tests. However, when the machines are excited from the same electrical source and the rotors operated at different speeds to accomplish the loading, the total input from the source is only that represented by the losses. This type of measurement allows much greater accuracy to be obtained in the segregation of losses and the determination of the stray load loss.

A series of tests recently completed at Worcester Polytechnic Institute were made to compare the various methods of determining stray load loss and particularly to validate the belted load back method. ("Stray Load Loss Test on Induction Machines," T. H. Morgan and P. M. Narbutovskih, ELEC. ENGG. (A.I.E.E. TRANS.), v. 53, Feb. 1934, p. 286–90.) These tests were made on identical motors rated 10 horsepower, 1,800 rpm, 3 phase, 60 cycles, 550 volts.

As a standard of reference for the other tests, a modification of the belted load back

test was used to measure the stray load loss in the most direct manner possible under actual load conditions. The rotors of the induction machines were coupled to calibrated d-c machines which were themselves loaded back on each other. With the induction machines at no load (slightly negative slip) and power circulating between the 2 d-c machines, the d-c input was adjusted to include all of the losses of the d-c machines and the no load losses of the induction machines. The a-c input was then zero. With the induction machines loaded, the currents in the d-c machines were kept at exactly the same values as initially, with the result that the d-c source still supplied the no load losses of the induction machines, and the a-c source supplied the losses due only to the change in load current. These losses are entirely I^2R and stray load losses. After all corrections had been made for minor changes, such as change in speed, the stray load loss determined in this way was found to be 2.9 per cent of full load output.

Tests made on the same machines when loaded back through a belt showed a stray load loss of 2.5 per cent. In connection with this method, it might be well to call attention to the manner of determining the belt slip loss described in the paper previously referred to. The belt slip should be determined from the actual pulley ratio and from the actual speed of the 2 machines as determined by mechanical or electrical stroboscopes. The belt slip loss is then the belt power or motor output times the ratio of belt slip to motor speed.

Tests made by exciting the stator of the machine with direct current showed that the stray load loss determined in this way is not the same function of equivalent a-c stator current as the actual stray load loss, but for these particular machines it compares favorably with the other results, giving a value at full load of 2.6 per cent. Loading of the induction motors on calibrated d-c generators was found to give a resulting stray load loss of 2.0 per cent, but as pointed out above, this is merely an input-output test and cannot be expected to be of comparable accuracy.

These tests demonstrate the worth of the load back method when both machines are excited from the same source, and the writers believe this method preferable to any other when identical machines are available. The fact that the test is made under actual load conditions and does not involve the inaccuracies of input-output measurements and that a minimum of testing equipment is required is much in its favor.

C. P. Potter (Wagner Electrical Corp., St. Louis, Mo.): The authors have presented a very concise yet complete description of the various methods recommended by the A.I.E.E. and N.E.M.A. committees for the testing of induction machines, and have made recommendations which are extremely practical. We agree that for motors up to 100 horsepower the dynamometer method is the most convenient and should, therefore, be the preferred method. While the separate loss method recommended for larger machines may not exactly duplicate actual load conditions, it at least provides a measuring stick which will be used by all those interested in determining the efficiencies of large machines.

At the present time motor manufacturers are accustomed to specify conventional efficiencies for most induction motors in the integral sizes. The adoption of the test methods described in this paper and covered by the test code recommended by the committees of N.E.M.A. and A.I.E.E., will make it necessary to revise the efficiency guarantees for integral size motors. This will entail a large amount of work and it will be some time before such a change can be completed.

The situation may be compared with the one which confronted the transformer manufacturers several years ago, when transformer efficiencies were based on measured core losses and copper losses calculated from resistance measurements taken at 25 degrees centigrade. It was generally recognized that the efficiencies calculated in such a way were incorrect, and it was therefore decided to change the rules and base transformer efficiencies on copper losses measured by wattmeter at 75 degrees. In this case it was a simple matter to measure the stray losses and comparatively easy to predetermine them before the transformers were built. In the case of induction motors, it is difficult both to predetermine the stray load losses and to measure them in a finished machine.

In spite of the difficulties involved, we believe that the adoption of the test code and the consequent change in the A.I.E.E. rules are steps in the right direction which should be taken in the near future.

R. E. Hellmund (Westinghouse Elec. and Mfg. Co., E. Pittsburgh, Pa.): The authors, while making brief reference to the calorimetric method, have not included it as part of their study. The usual calorimetric method, which consists of carefully measuring the amount of air flowing through a motor and determining the losses from the temperature increase of the air, will not be of great practical value or importance in the case of small motors. However, a similar method recently reported on by Roth to a subcommittee during the International Electrotechnical Commission conference at Prague seems to have considerable merit in connection with small and medium sized motors. In this test the entire motor is enclosed in a duct, as indicated in figure 2 of this discussion. The temperature rise of the air is measured by means of temperature indicators, G_1 and G_2, while the motor is loaded. Subsequently the motor is run at light load with increased voltage and the core and other no load losses are adjusted in such a manner that the temperature rise of the air is the same as during the load test. This then means that the losses at full load are the same as those that are measured with over-voltages at no load. If it is impossible to obtain sufficient losses at no load in the motor, extra known losses in resistors R can be added.

This method has the great advantage over the usual calorimetric method that no measurements of the amount of air are necessary and that all of the difficulties usually encountered in such measurements are avoided. The test is a purely comparative test, and if the temperature conditions of the inflowing air and of the walls of the duct are kept reasonably uniform, very satisfactory results should be obtained without an undue amount of care in the measuring, as is necessary with a number of other test methods. It is conceivable that whenever the wall temperatures of the duct cannot be kept reasonably uniform, some discrepancies might occur as the result of the radiation of heat from the motor to the walls of the duct; however, such variations probably can be kept to a negligible amount by supplying heat reflecting barriers K made of such material as bright aluminum sheet, for instance.

The equipment for such tests is quite simple and inexpensive and the method should therefore prove to be of practical value for any size of motor which it is feasible to enclose in a duct.

The authors make reference to a method proposed for testing stray losses which consists in exciting the stator of a squirrel cage motor with direct current and driving the rotor by an external force. The accuracy of this method seems questionable and in fact the method hardly seems to warrant any serious consideration because the magnetic flux and eddy current condi-

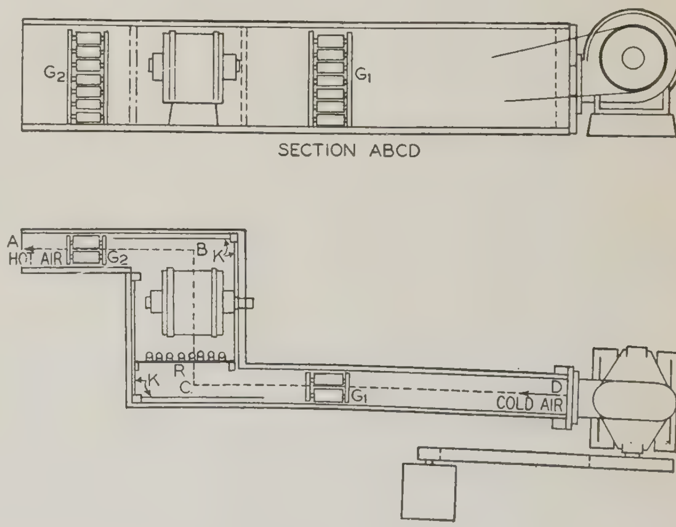


Fig. 2. Schematic diagram of duct arrangement for determination of load losses

Duct is constructed of fir boards with asbestos sheeting on all external faces for heat insulation

tions in a squirrel cage motor during such tests are so different from those obtained under actual load conditions. This is especially true in small and medium sized squirrel cage motors, for which a number of other and superior methods are available.

O. E. Stamm (New York Edison Co., New York, N. Y.): The methods presented in this paper are eminently suitable for test floor work when the degree of accuracy obtainable with them is required. The difficulties involved in using the various methods are clearly brought out. However, until it is realized that the need for determining the performance of induction motors in the field is frequently met with, the seriousness of these difficulties is not fully appreciated. In field testing, it is practically always necessary to test the motor in position, which may be ceiling mounted, supported on brackets, mounted on columns, or directly connected to some machine, in many cases in closely confined spaces. Therefore, the impracticability of utilizing dynamometer equipment, aside from any consideration of the range of ratings of such equipment which might be necessary to meet the testing needs, is evident. Similar machines, as required by the pump back test, are not available. In the direct method of determining the stray loss, it is necessary to use a driving motor. In field testing, this is generally impracticable. It seems to the writer that the present standards of the A.I.E.E. and the proposed American standards for rotating electrical machinery would, without any modification, permit the use of methods *a* and modified *a* and method *b* under paragraph 9–301 (*a*). Where these methods are not practicable, the conventional efficiency, the equivalent circuit, or the circle diagram must, of necessity, be used, and should be recognized in the standards. The data given on stray loss in this paper on the 30 horsepower motor on which detailed figures are given would indicate that it is of the order of one per cent. It would be of interest to know the order of magnitude of the stray loss for the motors on which results are given in table V. A more thorough appreciation of the importance of the stray losses would also be obtained if for purpose of comparison the conventional efficiency had been given for each motor in table V.

C. C. Leader and **F. D. Phillips:** The discussion has brought out a number of important questions and additional methods of measuring efficiency. O. E. Stamm has asked as to the magnitude of the load losses. In general, they are larger in small motors and smaller in larger machines. They vary with design and with the amount of care taken in manufacture. A good design of 10 horsepower motor will have about $2^1/_2$ per cent load loss. A motor of several hundred horsepower may have a loss as low as 0.6 per cent while a 5 horsepower motor with the high value of 7 per cent load loss has been tested.

Several speakers have inquired as to the accuracy of the various methods and their comparative accuracy. For the general accuracy to be expected, we would refer to an article by A. A. Emmerling, "Modern Equipment for the Precise Testing of Motors," in the *General Electric Review*, volume 37, page 471. We have had excellent results with the alternative dynamometer method suggested by Leader and find that it checks closely with the dynamometer method and the pump-back method with which we have compared it.

The calorimetric method of determining efficiencies as presented by R. E. Hellmund gives promise of both usefulness and accuracy. We have not had experience with this method but it seems to be worthy of continued study as recommended by the I.E.C. subcommittee.

The belted pump-back methods proposed by T. H. Morgan and V. Siegfried have some advantages and we are glad to learn that they are continuing their work on this and similar methods. A suggestion has been made that this method does not account for the losses in torque from internal friction in the belt as contrasted with belt slip losses but these are probably of small magnitude. We find, however, that a majority of the motors which we have been required to test for true efficiency are high speed machines, 1,800 or 3,600 rpm, which are too large for belting.

Power Losses in Induction Machines

Discussion and authors' closure of a paper by P. M. Narbutovskih published in the November 1934 issue, pages 1466–71, and presented for oral discussion at the induction motor session of the winter convention, New York, N. Y., January 24, 1935.

A. Van Niekerk (Westinghouse Elec. and Mfg. Co., E. Pittsburgh, Pa.): This paper is of merit because it emphasizes the importance of a detailed research into the nature of the stray load losses. Its closing paragraph, however, might give the impression that up to the present hardly any work relating to this subject has been done. This impression would be far from the truth; in fact, many interesting papers dealing with the stray load losses in induction machines have appeared in European technical literature during the last 10 years. As it would be impossible to review all these papers in this discussion, I should like to mention a few of the earlier ones.

An important paper dealing with the experimental side of the problem was published by Rogowski and Vieweg: "Additional Losses in Small Induction Motors" (*Archiv für Elektrotechnik*, 1925, v. 14, p. 574). Although it relates primarily to small and medium motors, its conclusions are broad enough to warrant the short review of its contents which now follows.

About 100 3 phase motors, of both the squirrel cage and the wound rotor types, had been subjected to highly accurate brake tests in the laboratories of the German government; in addition, the conventional test data (no load and locked test readings, d-c resistance of stator winding, and full load slip reading) had been determined with great care, so that the conventional losses by the indirect method (stator copper loss, core and friction losses, and rotor loss) could be computed readily. The sum of these conventional losses, called by the authors the "measurable" losses, was found to be always smaller than the actual losses determined by brake test, i. e., the difference of the latter minus the former, called the "additional" losses, was always positive. A list of 25 50-cycle motors from 0.33 to 20 horsepower, and their measurable and brake test losses, contained in the paper, reveals that at full-load the actual efficiencies are from 0.7 to 4.8 per cent (average 2 per cent) lower than the efficiencies determined by the indirect method. Of even more interest are the experimental rules indicating how the stray load losses vary with the load. It was found that:

a. The additional losses, in watts, plotted against the square of the stator current, follow practically a straight line.

b. The straight line mentioned under *a* remains practically unchanged when the line voltage varies while the line frequency remains constant.

c. The additional losses change with the line frequency (the line voltage remaining constant). In general, they were found to increase faster than the first, and slower than the second power of the frequency.

After presenting the experimental results, the authors discuss the possible causes and seats of the additional losses. They found in the first place that losses in solid stationary parts (brackets, etc.) attributable to stray fluxes set up by the end windings are practically zero. Calculations showed that the increase in stator copper loss from skin effect cannot amount to more than a few tenths of one per cent (in large motors the situation may be different, of course). It was further known that the friction and windage losses are practically independent of the load. From these facts the conclusion could be drawn that the main seat of the additional losses is in the core, where they increase the iron losses (fundamental, surface, and tooth pulsation losses) already present at no load. The surface and tooth pulsation losses at no load are mainly "reluctance" losses, caused by the variations in air gap reluctance by the slotting of the cores. Under load, however, there is another source of surface and tooth pulsation losses: the periodic changes in the relative spatial ampere-conductor distributions of the 2 members, which set up "saw tooth fields" that would be absent if said distributions would be continuous and sinusoidal all around the air gap. These fields pulsate at high frequencies and, as their intensities increase with the load, cause core losses that increase with the load. By winding test coils around the crowns of some of the stator teeth, the flux pulsations in these teeth could be recorded; the records clearly show that the amplitudes of these pulsations increase with the load. These tooth pulsations do not, however, induce any electromotive forces in the phase winding on the primary, and therefore the tooth pulsation losses are not covered by the primary circuit like the fundamental core losses. In fact, both the tooth pulsation and surface losses are consequences of the rotation of the secondary, and therefore are covered mechanically by the rotor (and not electrically by the rotor winding); this explains why these reluctance and saw tooth field losses are not included in the rotor losses computed from slip and power transmitted through the air gap. But as the reluctance losses are already included in the no load losses, only the saw tooth field

losses are neglected when efficiencies are calculated by the indirect method.

The behavior of a squirrel cage motor is essentially different from that of a wound rotor motor in so far as in the former the flux pulsations will induce high-frequency damping currents in the cage bars, thus causing an increase in rotor copper loss that is not included in the slip losses either. Oscillograms taken by the authors clearly reveal these higher harmonic currents in the cage bars, and show that their amplitudes increase with the load. The additional rotor copper loss could be estimated from the oscillograms and was found to be relatively small, amounting in one case to $^1/_6$, and in another to $^1/_4$ of the total additional loss. In motors with phase wound rotors, this additional rotor copper loss will be practically zero, but, as the damping influence of higher harmonic currents on the flux pulsations will be absent, the additional losses very probably will be higher in a wound rotor motor than in a squirrel cage motor of corresponding design.

The material contained in the paper was also presented by one of the authors at a meeting at Berlin (*Elektrotechnische Zeitschrift*, 1924, p. 988) which was followed by a discussion (*Elektrotechnische Zeitschrift*, 1925, p. 1011). On that occasion Ruedenberg stated that, in his opinion, the pulsation losses depend mainly on the ratio of air gap to tooth pitch. No additional losses occur if the air gap is longer than half the tooth pitch; with decreasing air gap these losses increase, first slowly, and then rapidly, it being well known that turning of the rotor of a given motor will decrease the stray load losses considerably. In addition, he claimed that the pulsation losses will be higher in silicon cores because, the skin effect being less pronounced due to the higher resistivity of silicon steel, the damping influence on pulsations inside of the core will not be as strong as in cores of ordinary sheet steel.

A paper more specifically devoted to a discussion of test methods suitable for making routine tests, "Test Methods for Determining the Stray Load Losses in Induction Machines," appeared in the *Siemens Zeitschrift*, 1927, page 223. A short account of the 4 test methods discussed follows here:

A. Brake test, or input-output method. Advantage: stray load losses directly found from operation under load (as the difference between the measured total loss and the sum of the individual losses computed by the indirect method). Disadvantages: not very accurate unless carried out with the utmost care; unsuited for large machines.

B. Circulating load test. Two identical machines belted together; pulley ratio (1–2 times full load slip); stators connected to a line supplying the losses; slip of each machine measured in order to determine belt losses. Stray load losses of the 2 machines equal to the difference between the total measured loss and the sum of individual losses (by the indirect method) plus belt losses; can be split up proportionally to the squares of the 2 stator currents. Advantage: same as under *A*. Disadvantages: inaccuracy in measuring the power supplied by the line on account of the very low power factor; unsuited for large machines.

C. Machine running as a synchronous motor carrying wattless load. Machine running idle with stator connected to line; rotor over- (or under-) excited by direct current until stator carries the desired load current; stator input measured. The method has several disadvantages: power is supplied to the stator at a very low power factor and therefore cannot be measured accurately; when the machine is underexcited, it has a tendency to pull out of step; the main flux density, which must be known in order to find from an ordinary no load test the no load losses to be subtracted, together with the stator copper losses, from the measured stator input, cannot be determined with great accuracy; at higher current values (near full load current) the losses increase much faster than the current squared, and are then positively too high. Hence method not suitable for determining the stray load losses in induction motors.

D. Short-circuit method. Machine driven at normal speed by a calibrated d-c motor; stator short-circuited; rotor excited until stator carries the desired load current. Stray load losses put equal to the difference between the power input (shaft) and the sum of friction and stator copper losses. For commercial purposes, the machine can be driven at synchronism and the rotor excited by direct current. In the author's opinion (based on a comparison of results obtained by methods *A* and *D*) the assumption that the losses thus found are identical with the actual stray load losses in the loaded machine is sufficiently accurate for technical purposes, although in the rotor the d-c belt distribution during the test is not the same as the a-c belt distribution under actual load conditions. He has checked this point by making additional tests with the rotor excited by low frequency 3 phase currents supplied by an a-c exciter, and found that the discrepancies in results for the 2 methods of exciting the rotor are relatively small.

The author found that with the exception of method *C* at higher current values all methods give good results which come close to the straight line loss characteristic previously mentioned; he states that method *D*, the easiest one for routine tests, will give the best results, adding, however, that this method cannot be applied to squirrel cage motors, which should be tested by method *A* or method *B*

A quite elaborate report on the possibilities of test *D* was published by E. H. Linckh: "On the Determination of Stray Load Losses in Induction Motors" (*Archiv für Elektrotechnik*, 1929, v. 23, p. 19). Of interest is the statement that the losses found by test *D* are always higher than the actual stray load losses by brake test; the explanation given is that the 2 tests are carried out under entirely different conditions of magnetization. In connection herewith the author proposes to use certain correction factors in connection with method *D*. He further states that method *D* is also applicable to squirrel cage motors, and that different correction factors must be used for wound rotor, squirrel cage, and double deck motors.

The first serious attempt to establish a complete theory of high frequency core losses, including those constituting the greater part of the stray load losses, has been made, to my knowledge, by L. Dreyfus: "Theory of Additional Core Losses in Polyphase Induction Motors" (*Archiv für Elektrotechnik*, 1928, v. 20, p. 37, p. 188, p. 273). This highly theoretical paper has been supplemented by L. Dreyfus and S. E. Eriksson: "Additional Losses in Induction Motors" (*Elektrotechnik und Maschinenbau*, 1927, p. 737, p. 756, p. 881, p. 904), a paper which presents the subject to the practical engineer and gives an account of research work done in support of the Dreyfus theory.

This theory deals with the high frequency core losses occurring in wound rotor induction motors at the air gap surfaces (tooth crowns), in the teeth, and in the cores just back of the teeth, in the form of eddy current and hysteresis losses. A method is presented for computing the eddy current losses with a reasonable degree of accuracy, taking into account, where necessary, the influence of skin effects. The discussion of the hysteresis losses is more of a qualitative nature, although a few formulas are given by means of which the additional hysteresis losses in tooth crowns and tooth bodies (those in the cores back of the teeth can be neglected) can be estimated. Dreyfus proves that the reluctance and the saw tooth field losses can be calculated separately and then added, without introducing an appreciable error (the former hardly change when load is applied to the machine; the latter, practically negligible at no load, increase rapidly with the load).

A few statements made by Dreyfus in his *Elektrotechnik und Maschinenbau* article concerning the test methods for determining the stray load losses are also of interest, but cannot be repeated here in an abridged form.

Although it cannot be said that the Dreyfus method is something final and readily applicable by the designer of commercial apparatus, it constitutes, in my opinion, a very important step in the right direction and should not be left unconsidered by those who, on the basis of theoretical investigations and experiments, must develop practical methods or short cuts for computing or estimating the stray load losses in induction machines.

T. H. Morgan and **V. Siegfried** (Worcester Polytechnic Institute, Worcester, Mass.): The division of the core loss between the fundamental and rotor tooth frequency components can be determined experimentally at no load by a simple measurement involving the use of a rated d-c motor directly coupled to the induction machine. This motor should be so chosen that the no load losses of the induction machine are a substantial portion of its rating, and a careful determination of its losses should be made. If the rotor of the induction machine be driven at synchronous speed, as indicated by a stroboscope, the fundamental frequency iron losses and stator I^2R losses will be supplied by the a-c source, and the rotor tooth frequency iron losses will be indicated by an increase in the d-c input over the power required to drive the unexcited a-c machine. Due to the presence of a torque on the rotor caused by hysteresis of the rotor iron, these measurements must be made with the rotor revolving with an exceedingly small slip, first above then below synchronous speed. The average of these 2 readings cancels out the hysteresis torque power, which changes sign as the slip is reversed. If, then, the rotor be driven above synchronous speed until the a-c input is only that required for stator copper loss, the increase of d-c input over the unexcited power will be the entire core loss, both at fundamental and rotor-tooth frequencies. Rotor copper loss is negligible in both cases.

Measurement of these quantities on a typical machine showed the major portion of the core loss to be at fundamental frequency. A 10-horsepower 1800-rpm 3-phase 60-cycle 550-volt machine was driven by a 1 horsepower rated d-c motor. At synchronous speed the average a-c power, representing the fundamental frequency core loss, was 206 watts, while the increase in d-c power, required to supply the rotor tooth frequency core loss, was 52 watts. Driving the rotor ahead to supply all of the

core losses through the d-c machine showed them to be 258 watts. The hysteresis torque power was found to have a value of 38 watts.

With this information at hand, the correctness of assigning all of the core losses to the secondary portion of the equivalent circuit (as proposed in various testing methods) might be questioned.

P. M. Narbutovskih: A. Van Niekerk gives a fine résumé of practically all (to the author's knowledge) that was written on the subject of the stray load loss in induction machines. At the time of publishing the paper the author was not aware of the existence of this literature, and discovered it only some time later.

Since the article by Rogowski and Vieweg is mentioned by Van Niekerk, it might be of interest to call attention here to an effect of load upon the high frequency eddy currents in the bars of a squirrel-cage motor. The effect was observed in the course of an experimental study of the sources of stray load loss in induction motors. As a result of this observation the statement made in Rogowski and Vieweg's article concerning the negligibly small value of the eddy current loss in the rotor bar can be questioned.

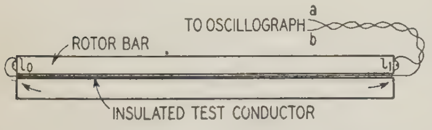


Fig. 1. Device used for recording rotor bar currents

A few preliminary statements will help to explain the situation. The device used by Rogowski and Vieweg for recording the squirrel cage bar currents is shown in figure 1 of this discussion. It can be shown that if no current flows in the test conductor, the instantaneous value of voltage produced between leads a and b is given by the integral

$$e = \int_{l_0}^{l_1} \rho\delta \cdot dl = \int_{l_0}^{l_1} \rho\delta \cos \gamma \; dl$$

Where

ρ = resistivity of the material of the bar
δ = current density at any point in the bar along the test conductor
γ = angle between the direction of the test conductor and the direction of the current flow at any point along the conductor. Since the direction of current flow is coincident with the direction of the test conductor for the greater part of the path, $\cos \gamma = 1$, except at the very ends of the bar.

In other words, the voltage appearing between conductors a and b equals the voltage drop between points l_0 and l_1, due to the current within the bar flowing in the immediate neighborhood of the test conductor. Unless the current density within the bar cross section is uniform, test conductors placed in various parts of the bar must obviously give different records, a fact which was, apparently, overlooked by Rogowski and Vieweg. This gives a possibility of experimentally investigating the current density distribution within the bar cross section.

Tests performed according to this scheme show that along the outer and side surfaces of the bar heavy high frequency currents flow, due to the stator teeth. The amplitude of these currents varies with the air gap flux density, i. e., at the slip frequency of the rotor, from nearly zero, for zero value of induction, to over 10 times the amplitude of the fundamental useful current at full load. The amplitude decreases rapidly with the distance from the surface of the bar. Roughly, the amplitude reduces to $^1/_{10}$ of its value on the surface at a distance $^1/_3$ of the depth of bar down, and $^1/_4$ of the width from one side. Machine used is rated at 10 horsepower, with rotor bars $^5/_8$ inch wide, $^1/_2$ inch deep, and 8 inches long.

The effect of load is to increase considerably the amplitude of the eddy currents in the region of the outer trailing corner of the bar, and to reduce it in the region of the outer leading corner (outer meaning the one farthest from the axis of rotation). It was supposed that the phenomenon was caused by the saturation of the rotor tooth shoulders (semiclosed slots) due to the rotor leakage fluxes. As a check, the machine was run as an induction generator, which gave a complete confirmation of the hypothesis; with load pulsations increased in the leading corner and decreased in the trailing one. A glance at figure 2 of this discussion will explain the mechanism of the phenomenon. The trailing and leading tooth shoulders operate at different values of magnetic induction, which is a result of superposition of the fundamental and leakage fluxes, and therefore at different values of permeability. Hence, the shoulders offer a different degree of magnetic shielding of the bar from the high frequency components of flux due both to the stator reluctance and magnetomotive force distribution. In other words, the effect of the rotor leakage fluxes upon saturation of the tooth shoulders is equivalent to a variable effective width of the slot opening.

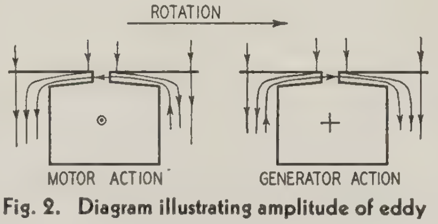


Fig. 2. Diagram illustrating amplitude of eddy currents

The actual oscillographic records of bar currents obtained in the laboratory are quite complicated, and therefore a detailed discussion of the information contained therein is omitted here.

The information submitted by T. H. Morgan and V. Siegfried is of an undoubted practical value. It would be of interest to compare similar measurements made on various motors, especially in view of the statement made by other investigators that the measured iron loss in induction motors is greater (and in some cases several times greater) than the computed iron loss. The increase has been attributed primarily to the tooth pulsation loss, which supposition is not supported by Morgan and Siegfried's measurements.

Transient Voltages on Bonded Cable Sheaths

Authors' closing discussion of a paper published in the January 1935 issue, pages 73–82, and presented for oral discussion at the cables session of the winter convention, New York, N. Y., January 24, 1935. Other discussion of this paper was published in the April 1935 issue, page 436.

Herman Halperin, J. E. Clem, and K. W. Miller: When the switching operations on high voltage cables with specially bonded sheaths are confined to windings of the power transformers other than those to which the high voltage cables are connected, as in the case mentioned by E. R. Thomas, then it seems likely that the transient sheath voltages would be considerably smaller than when switching is done at the line voltage.

A correction for table VII of the paper is as follows:

Under the heading "Sheath Surge, Case (2)" the values of e_{BB}/I and e_{10}/I should read xze'/D and $(xze'/D) - ze''/2$, respectively.

In line with the remarks made by G. B. Shanklin and D. M. Simmons after the presentation of this paper at the convention, it should be noted that the use of insulating sleeves to eliminate sheath losses on single conductor cables has been highly satisfactory from a technical standpoint as well as from economic considerations. Experience subsequent to the preparation of the paper has again demonstrated that there are no technical difficulties in developing sheath bonding transformers to successfully withstand transient sheath voltages. These latter transformers were purchased with a specification requirement that the insulation withstand an impulse test of 16 kv, which value was considerably above the maximum transient voltage found imposed on the sheath bonding transformers in Chicago.

Dielectric Properties of Cellulose Paper

Authors' closing discussion of a paper published in the October 1934 issue, pages 1389–96, and in the November 1934 issue, pages 1498–1503, and presented for oral discussion at the cables session of the winter convention, New York, N. Y., January 24, 1935. Other discussions of this paper were published in the March 1935 issue, pages 322–4, and in the April 1935 issue, pages 431–4.

J. B. Whitehead and E. W. Greenfield: The figures for per cent moisture content as indicated in the title of table II, and in connection with the formula upon which the computations are based, are the minimum amounts of moisture necessary to account for the variation in properties as observed. Wherever elsewhere in the paper reference is made to the amounts of moisture these minimum values are to be understood.

These minimum values are computed on the assumption that all of the moisture in

the paper exists in solid layers or films parallel to the electric field. If, on the contrary, all of the moisture be assumed to be in layers normal to the field, we may compute the maximum amount of moisture consistent with the experimental observations. The formula for the maximum moisture content in per cent of total volume would be as follows:

$$M = \frac{K_w(C_\infty - C_0)}{C_0 K_\infty (K_w - 1)} \cdot 100$$

G. M. L. Sommerman's formula for the same quantity is in agreement. The corresponding maximum possible amounts in per cent of total volume would be 0.43, 0.6, 0.77, 1.02, 1.47, and 2.14, for the 6 pressures beginning with 0.25 millimeters of mercury and ending with 765 millimeters of mercury, respectively, as given in table II. Obviously neither of these pictured extreme distributions of moisture exists in any actual case. The true values for each pressure are probably approximately the mean of the minimum and maximum values as given.

Louis Meyerhoff and Sommerman call attention to the uncertainty of the value of the dielectric constant of water as related to the degree of dryness. To this view we subscribe. However, the possible range of values, and particularly the average condition as between the series and parallel relation of the water layers of the direction of the field make it probable that there would be little change in the approximate values of moisture content as given.

We are particularly interested to see the suggestion of J. A. Duncan that the Freundlich equation for adsorption isotherms may explain the simple relation we have found between moisture content and pressure. The connection indicated seems to us highly probable and we are happy in the added support thus given to the validity of our method and conclusions.

R. W. Atkinson and F. W. Godsey, Jr., raise the question of the influence on dielectric loss of the presence of impurities other than water in cellulose paper. Their comments are in line with our own, described at the opening of the paper, on the general properties of paper for insulation purposes. Our figure 12 in fact suggests the possibility of a very small value of loss at zero moisture content. Certainly, however, no other impurity has anything approaching the influence that water, with its high dissociating properties, has on conductivity, phase difference, and loss in high quality dielectrics. This long-known result is borne out by our own experiments, as indicated particularly in figures 8 and 12. There appears to be no reason to speculate here as to whether pure cellulose or pure rosin could be shown to have electrical conductivity or loss not due to admixed moisture. This question has, in fact, no important bearing on the conclusions of our paper. It arises only in connection with the deductions from figure 8, and here only indirectly. The important matter is that all of the quantities studied decrease markedly with decreasing moisture and in accordance with apparently regular laws. The conclusions of the paper are based on these definite experimental relationships to moisture content and to temperature, and assume the influences of other impurities to be negligible, or rather to play no part in variations which are clearly due to removable moisture.

Atkinson and Herman Halperin have presented figures on temperature changes of capacitance in cables of various dimensions. The figures range from a very small fraction of 1 per cent all the way up to 4 per cent or 5 per cent. It is stated that diametral changes alone in these cables would not account for the higher ranges of observed values. To this we agree. No explanation of the observed increases is offered. Note, however, that some of Halperin's figures are sufficiently low to be accounted for by just this type of change. Observed increases in our samples are completely accounted for by simple thermal expansion. It appears to us not improbable that if longitudinal expansion and possible internal deformation, as the result of sheath stretching or other cause, be taken into account, it may well be found that the entire observed increases in cables may be due to dimensional changes rather than to inherent properties of the dielectric. The only apparent alternative is the presence in the cable of so much gas that the thermal expansion of the impregnated material may cause a reduction of gas volume in favor of dielectric, sufficient to account for the observed changes in capacitance. We believe that few cable engineers will accept this explanation.

Meyerhoff raises a question as to the accuracy of our figures on the thermal expansion of the brass tube, and the consequent changes observed in dimensions. We agree that the figures are abnormal as for brass, and we have devoted considerable study to this question. In view of its importance, as related to our conclusions, we have repeated the measurements using other observers, but under similar conditions of experiment, and the figures as given in the paper are closely confirmed. Two possible explanations suggest themselves. One is the chemical constitution of the material of the tube. Certain alloys involving large proportions of tin, for example, have thermal expansion coefficients close to the average values observed by us. We believe a more probable explanation, however, is to be found in a state of strain which is sometimes set up in the manufacture of seamless drawn brass tubing. It is known that under such conditions, abnormal values of expansion coefficients may result.

Meyerhoff also suggests that our values of capacitance as observed might be accounted for by changes in density due to compression of the dielectric, rather than to the change in electrode dimensions as reported. We agree with his figures on density changes as far as they go. However, in addition to compression by the electrode, the paper is also stretched circumferentially and longitudinally, owing to the change in the dimensions of the brass. The estimated values of these somewhat uncertain factors are just about sufficient to offset the figure for increased density given by him. We note with interest his suggestion that the variation of dielectric constant of water with temperature might be made the basis of an extension of our method of studying the effect of moisture content on electrical properties.

A. M. Myers has made a very pertinent comment on an essential difference between our method of drying and measuring and his own. It undoubtedly accounts for the differences in power factor as between his measurements and ours. As a consequence it also means that the amounts of moisture remaining in our specimens are substantially less than in his and therefore it seems to us a quite adequate explanation of the fact that our computed values of the moisture content are substantially lower than any he has observed. Incidentally this appears to mean that in the factory drying of cables, the amounts of moisture remaining in the paper may be substantially greater even than any of our computed values. This raises the question as to the influence of such residual moisture on the final impregnated insulation.

R. J. Wiseman seems to find in our results evidence of the sufficiency of the drying methods used in the manufacture of cables. I do not feel, however, that we can go all the way with him in this. He speaks of drying pressures within the range of from 4 to 5 millimeters. The results for the moisture content indicate values of residual moisture of from 0.4 to 0.5 per cent by volume. Until the questions as to what this moisture does after the paper is impregnated and as to what effect it has on oil stability and life are answered, I do not think it is safe to conclude that we need not seek further for improvements in our drying processes. Incidentally, we note an error in figure 11 of the paper as published. The decimal points in the scale of ordinates, i. e., power factor, should be moved one place to the left. This means that our low values are about the same, or slightly lower than the extreme values quoted by Wiseman.

Dielectric Strength of Mineral Oils

Author's closing discussion of a paper published in the January 1935 issue, pages 50–5, and presented for oral discussion at the cables session of the winter convention, New York, N. Y., January 24, 1935. Other discussions of this paper were published in the March 1935 issue, pages 326–7.

F. M. Clark: In my discussion of the comments submitted by C. S. Sprague, J. B. Whitehead, F. W. Godsey, Jr., and Preston Robinson, I am confining my remarks to Whitehead's severely critical analysis.

His opinions in the field of dielectric phenomena are usually well-founded and reflect serious consideration, and with them I hestitate to disagree. His position in this instance, however, appears untenable. He suggests that the correlation of mineral oil breakdown and gas phenomena cannot be supported because of "much other evidence" as for example (*a*) difficulty of repetition, (*b*) wide variations between dielectric strength and pressure, (*c*) importance of impurities, and (*d*) conditions at the electrode surface. It is difficult to answer such unsupported contentions. Perhaps we may expect a contribution by him in which he will show that the dielectric strength of oil is not affected by the increasing gas content or, better still, that the dielectric strength falls with increasing gas pressure applied under testing conditions similar to those of the present paper.

At this time I can only assure him that there is no evidence among the extensive data which I have collected in my own laboratory or which have come to my attention in the literature which would show a wide variation in the effect of gas pressure on the dielectric strength of mineral oil. With increasing gas pressure, increasing dielectric strength always results. The behavior is not difficult of repetition. With proper attention to testing technique, the dielectric strength of mineral oil is easily reproducible within the limits normally expected in dielectric phenomena. A recent article by E. Scheu (*Archiv. für Elektrotechnik*, volume 29, page 192), discusses the testing procedure capable of reproducing dielectric strength values with an expected scattering of not more than from 5 to 7 per cent from the average. Procedure such as outlined, with adequate "rest" periods covering several hours, has invariably been followed in obtaining the author's results outlined in the paper.

As concerns impurities and conditions at the electrode, one would be foolhardy to suggest a constancy of physical behavior under all possible testing conditions of contamination or otherwise. No such claim has been made. The article concerns mineral oil as representative of liquid dielectrics tested under normal voltage application procedure. It makes no attempt to consider contaminated liquids although in a previous article it is stated that "the dissolved gas (in oil) is considered as the major impurity. Secondary impurities which act only in their effect on the dissolved gas characteristics are dust particles, fibers, and other insoluble or partially soluble foreign materials." (Franklin Institute *Journal*, 1933, volume 216, number 4, page 431.) The experience of the author has been that although such impurities may affect the absolute value of dielectric strength, within normally occurring limits of contamination, the response of dielectric strength to gas pressure change is in accordance with the expected behavior.

Whitehead next claims that the impulse breakdown of an oil is independent of pressure and within wide limits of the dissolved impurities. With this the author has no disagreement. The impulse type of electrical breakdown was considered as beyond the scope of the present paper which confines itself entirely to the normal 60 cycle type of oil breakdown test. The author has already discussed the impulse behavior in a previous paper in which the broader aspects of the problem were treated. I quote from the section entitled "The Time Factor" which appears on page 453 of the *Journal* of the Franklin Institute for 1933, volume 216, number 4: "Gaseous breakdown involves a time factor of exceedingly short duration. Since the breakdown of 'impure' (gas containing) liquids involves secondary factors affecting gas elimination in addition to gaseous ionization, the time to break down should be of longer duration. This is true. The shorter the time interval, the more nearly the breakdown approaches that characteristic of the same liquid under impulse voltage, and, as has been shown also, the less the difference between the 'pure' (degassed) and the 'impure' (gas containing) classification." Or again quoting from the same article, "with decreased time, the impulse breakdown is gradually approached and the gassing type of electrical breakdown merges into the impulse or (oil) molecular ionization type." The information in parenthesis is inserted for clarity.

I see no basis for the contention that a relation should exist between conduction phenomena and the dielectric breakdown of mineral oil. Gas-containing oil breakdown differs from gaseous breakdown in that it involves a complexity of substances (liquid and gas) and that it occurs in normally good oil with unexpected rapidity and "explosiveness." Should the rupture of air saturated oil involve the separation of a gas bubble, and this possibility is not denied, the conduction characteristics of the oil before the gas separation would not be expected to show relation to the rapid sequence of events occurring when such a gas bubble is discharged into a field of high intensity, far above the gas ionization potential. Experience fails to show any relation between the type or degree of conduction in dielectric liquid and the dielectric strength. Air saturated liquids widely varying in molecular make-up or mineral oils differing widely in physical characteristics all respond with increased dielectric strength when tested under increased gaseous pressure.

In the first 2 paragraphs of the article under discussion, reference is made to 2 previous articles describing the dielectric behavior of insulating liquids in the light of gas solution phenomena. I again suggest reference to these previous publications for further data which were considered as "beyond the scope of the present paper," which limited itself only to a discussion of mineral oil containing dissolved air and tested in accordance with the usual procedure of voltage application. These previous publications may alleviate the regret "that the author has not presented more experimental data."

Whitehead next objects to the reference made to the work of Kock. Referring to this work he says, "Moreover, his (Kock's) oils were free of gas." Reference to Kock's work reveals no such condition. Kock used an arrangement for his pressure application involving a hydraulic pump and gas pressure tanks of air and carbon dioxide. It is apparent from the object of his researches (the use of gas under high pressure in transformer design) as well as the precautions taken to prevent gas bubble entrapment during the preparation of his samples for test that Kock's liquids contained dissolved gas. The reference to Kock was made merely to illustrate the behavior of oil at pressures higher than 3 atmospheres, the limit of pressure investigated by the author. Other illustrations might have been used with equal force.

And, finally, Whitehead suggests an alternative hypothesis to explain the behavior saying ". . . the experiments quoted do indicate the type of correlation proposed by Clark." The suggestion says (*a*) the ionization involves a loosely bound electron of the oil atom, (*b*) these loosely bound electrons are chemically active and are involved in oil oxidation, and (*c*) increased air in the oil merely ties down or restrains loosely bound electrons and thus diminishes secondary ionization. He suggests experiments involving gases other than air. With his hypothesis I have little sympathy. It is obviously a manifestation of his desire to explain electrical breakdown of oil in terms of conduction phenomena. The reversibility of the dielectric strength-pressure relation, the normal response of the dielectric strength of oxidized oil to pressure change, the similarity in the behavior of widely varying chemical types of insulating liquids, the similarity in the pressure-dielectric strength relation for dielectric liquids irrespective of the type of gas used to obtain pressure change, and the high dielectric strength obtained when the gas content of the oil is reduced to a value corresponding to a few microns of gas pressure are all factors which cast doubt on the validity of any such type of speculation. Specifically, in answer to his suggestion concerning the use of different gases, I refer him again to the previously mentioned article (page 39, volume 215 of the *Journal* of the Franklin Institute for 1933) in which experimental data concerning the dielectric strength of oil as a function of its gas content is described. The gases used are hydrogen, air, and carbon dioxide. The increased dielectric strength of oil under increased nitrogen gas pressure is usually recognized. The type of gas used to produce increased oil dissolved gas content is not of major importance. The controlling factor is the changing quantity of oil dissolved gas, a factor which has been expressed in the present paper as the oil-dissolved gas density. The use of such terminology reflects the attempt to correlate the breakdown of gas-containing dielectric liquids and the breakdown of gases, modified "as is necessary by the affinity of the molecules of the solute (gas) for the molecules of the solvent (oil)."

Cable System Neutral Grounding Impedance

Author's closing discussion of a paper published in the January 1935 issue, pages 30–40, and presented for oral discussion at the cables session of the winter convention, New York, N. Y., January 24, 1935. Other discussions of this paper were published in the March 1935 issue, page 324, and in the April 1935 issue, pages 434–6.

J. E. Clem: Most of the discussion of this paper questions the soundness of the original theory (presented by Doctor Petersen) on which it is based. The author wishes to emphasize the fact that he holds no brief for any particular theory and that if and when a better analysis of the arcing ground phenomena appears than that used by him as the basis of the development in the paper, he hopes to be among the first to accept it. Inasmuch as there seems to be such a fixed difference of opinion as to whether arcing ground overvoltages actually exist and if they do, how they develop, the author feels that nothing will be added by continuing the discussion.

The statement that the proposal to limit the calculated arcing ground voltages to 3 times normal had been "tentatively . . . accepted by the operators" was made in good faith, but it appears to have been based on misinformation. It is regrettable that this mistake was not called to the author's attention in the approval stage.

Heat Flow in Turbine Generator Rotors

Author's closing discussion of a paper published in the October 1934 issue, pages 1359–65, and presented for oral discussion at the electrical machinery session of the winter convention, New York, N. Y., January 22, 1935. Other discussions of this paper were published in the May 1935 issue, pages 555–7.

C. E. Peck (Westinghouse Elec. and Mfg. Co., E. Pittsburgh, Pa.): The writer appreciates the thorough study made by Snell in applying the calculation to a large turbine generator rotor. His study emphasizes especially the desirability and in many cases the necessity of separately studying the different sections of the rotor which do not have similar cooling conditions and arriving at a temperature rise constant for the rotor body which is a weighted average of the temperature rise constants obtained from calculating the different sections separately. This extension of the analysis is important in long rotors in which the axial and radial velocities of the cooling medium vary greatly from the end to the center of the rotor body, in which case the use of a single average value for each of the various heat transfer coefficients is not accurate enough. This point was not mentioned in the paper and the writer considers Snell's study an important addition to the paper. The satisfactory agreement between calculated and test values indicates that Snell has paid particular attention to the importance of having available a reliable and representative set of physical constants to apply to the calculation method.

Comments upon the choice of constants have been given by Mortenson. The importance of air pockets in the insulation cannot be underestimated and average values of the equivalent air film can be obtained only by carefully conducted tests, preferably on a model coil. In the rotor the effect of the air pockets on the accuracy of the calculation is not as critical as in the stator because the thermal drop across the insulation is not as large a proportion of the total thermal drop as in the stator, particularly on the higher voltage machines. When constants are determined by test methods, it is very desirable to make more fundamental studies of a developmental nature, preferably on elements in the form of models because many variables can be studied and more comprehensive and fundamental relations can be derived from the tests. The results thus obtained may be applied successfully to a wide range of sizes.

The analytical methods outlined in the paper enable one to predetermine the effect of various schemes for increasing the rotor output. In many cases an investigation of this type shows that what looks to be a promising scheme does not give enough gain to justify the cost of adopting a new type of rotor construction.

The methods of calculation shown in the paper could be adapted to estimate the gain from the use of the ventilating scheme illustrated in figure 6 of Mortenson's discussion. Test data would be needed on the velocities of air in the vent ducts, but such velocities have been determined by model tests. The calculation could then be used to determine whether or not the scheme could be used to advantage on a full size rotor. The calculations are useful for analyzing test results as well as studying the effects of changes to obtain more output.

In conclusion, the writer wishes to point out that the present paper is a direct application to the rotor of the equivalent thermal circuits which have been previously worked out by C. R. Soderberg in his paper "Steady Flow of Heat in Large Turbine Generators," A.I.E.E. TRANSACTIONS, volume 50, June 1931, pages 782–98. His work justified the use of the equivalent thermal circuit of the form shown in the paper for solution of 2-dimensional heat flow problems because he compared the results obtained, using the circuit with an independent fundamental mathematical treatment of the 2-dimensional steady heat flow problem applied to the slot region of an electrical machine. His work made possible the reasonably complete application given in this paper and shows how valuable a tool the equivalent thermal circuit is for solution of heat flow problems in electrical machines.

Transients in Magnetic Systems

Author's closing discussion of a paper published in the March 1934 issue, pages 418–25, and presented for oral discussion at the electrical machinery session of the winter convention, New York, N. Y., January 22, 1935. Other discussion of this paper was published in the May 1935 issue, page 557.

C. F. Wagner (Westinghouse Elec. and Mfg. Co., E. Pittsburgh, Pa.): Weber raises the question that for small air gaps the assumption of uniform flux density in the air gap cannot be correct. With this I quite agree. Neither is the assumption of equal radial distribution in the iron and air gap correct. Actuality lies somewhere between these 2 assumptions. The particular value of my paper in the realm of small air gaps is that it provides a second limiting value within which the actual solution must lie. Without this analysis there would always have been some speculation as to the accuracy of the assumptions of previous investigators. Perhaps this point was not stressed sufficiently in the paper. Figure 1 of this discussion shows the calculated difference for the 2 assumptions. The constants chosen are marginal for a large synchronous machine.

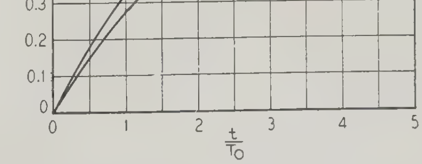


Fig. 1. Limiting curves for flux distribution
A. Assuming uniform flux density in air gap
B. Assuming radial distribution of flux density same in air gap and solid part of iron
$\frac{T_s}{T_o} = 4.0 \quad n = 0.5$

In this connection I could have calculated and plotted the curves of figure 3 of the paper using different parameters. Thus a family of curves with $\frac{\theta}{T_o} = n\frac{T_s}{T_o}$ constant might have been determined for different values of n. The difference between the curve for which $n = 1$ and any other curve would then give the difference between the solutions for the 2 assumptions under discussion.

Impulse and 60 Cycle Strength of Air

Discussion and authors' closure of a paper by P. L. Bellaschi and W. L. Teague published in the December 1934 issue, pages 1638–45, and presented for oral discussion at the transformer symposium of the winter convention, New York, N. Y., January 22, 1935.

C. M. Foust (General Electric Co., Schenectady, N. Y.): The authors have summarized some very interesting data in their paper. While they have applied humidity and air density sparkover corrections in some cases, still it is apparent that more precise information on these is required. As work on the strength of air proceeds, this matter of corrections becomes more difficult to take care of. Corrections for humidity and air density appear to vary with wave shape and polarity of the applied voltage, electrode shape, field configuration, and voltage level. For the present, an established procedure of carefully recording all test conditions will undoubtedly prove helpful.

The curves and tables presented again call attention to the great influence of polarity on sparkover when dissimilar electrodes are used. The authors conclude that "the flashover voltage is lowest when the positive polarity is applied to the electrode where the electric field is most intense." In connection with the rod-plate tests described, a slight extension above the plate resulted in sparkovers occurring consistently to the extension when it was positive in polarity. With the extension negative in polarity sparkovers took place partly to the rod extension and partly to the adjacent surface of the plate. The protective cone of the positive extension therefore includes the entire plate and is decidedly greater than that of the negative extension. This phenomenon was pointed out by Lewis and Foust in the *General Electric Review*, August 1931, in connection with the polarity of lightning currents in transmission line tower structures. Since that time additional data on these currents have been accumulated. Tower currents resulting from lightning strokes are almost

exclusively negative in polarity, that is, the tower top is negative relative to the tower base. This suggests a negative cloud with the tower acting as an extension above the positive ground and serving as a terminal for all negative cloud strokes within a wide area. The laboratory tests described by Bellaschi and Teague again bear this out.

J. C. Dowell (General Electric Co., Pittsfield, Mass.): The authors have used a humidity correction factor of 3 per cent per grain per cubic foot for their rod gap and rod to plate gap 60 cycle sparkover data. Similar 60 cycle data obtained in Pittsfield during the past several years indicates that this correction factor for the rod gap is not a straight line, but is a curve. The correction factor of 3 per cent is a fairly good average and close enough for general use over the range of humidities below 6.5 grains per cubic foot, but for humidities above 6.5 grains the curve departs appreciably from the average value of 3 per cent. For example, in correcting 8.5 grains down to the standard value of 6.5 grains per cubic foot, Pittsfield data indicates a correction factor of only 1.7 grains per cubic foot. While the deviations mentioned are not appreciable for the range of humidities over which the data presented were taken, it does indicate a possibility for further refinement along this line.

It is noted that the impulse time-lag curves given on the different type gaps stop at 2 microseconds. It would seem that from the standpoint of the design engineer the most valuable time lag data exists in the range of time lags below 2 microseconds. The writer would like to ask if this time is the limit of the recording equipment.

The time lag data presented in figures 11 and 12 indicate that the positive and negative sparkover curves given in figure 13 are not for a constant time to breakdown but probably vary over quite a range. It would seem that these curves in figure 13 would be of more value if plotted for a constant time-lag condition for the different gap spacings.

W. L. Lloyd (General Electric Co., Pittsfield, Mass.): The results given in this paper are of considerable theoretical interest. That these results are in agreement with previously published data will be of general satisfaction. There is close agreement between the data on the rod gap and the data in "Flashover Voltages of Insulators and Gaps," Electrical Engineering, June 1934, pages 882–6, and "Impulse Flashover of Suspension Insulators and Rod Gaps," *General Electric Review*, December 1934; and, as mentioned in the paper, the sparkover data for the point-to-plane and sphere-to-plane gaps are in good agreement with those of Goodlet, Edwards, and Perry published in 1931.

Not mentioned by the authors and presumably overlooked by them is the remarkable agreement between their conclusions and those of earlier investigators. As early as 1915, for example, it was pointed out that the effect of polarity on the impulse sparkover of air gaps varied with the degree of dissymmetry of the electrodes. Thus, "for dissimilar electrodes, impulse sparkover takes place at the lowest voltage when the electrode in the densest field is positive. For uniform and fairly uniform fields a difference between + and − rupturing voltages cannot be detected" from a 1915 paper ("The Effect of Transient Voltages on Dielectrics," F. W. Peek, Jr., A.I.E.E. Transactions, volume 34, 1915, part II, pages 1857–1909) is almost identical with the main conclusion of the 1935 paper by Bellaschi and Teague. This conclusion is the one having chief practical importance. It is, however, 20 years old.

P. L. Bellaschi and **W. L. Teague**: Referring to J. C. Dowell's discussion, his comments on humidity corrections are in line with our experience.

The characteristics of rod and sphere gaps on very short impulses have been published. (Refer to "Factors Influencing the Insulation Coördination of Transformers—II," P. L. Bellaschi and F. J. Vogel, Electrical Engineering, June 1934, pages 870–6, and "Sphere Gap Characteristics on Very Short Impulses," P. L. Bellaschi and W. L. Teague, *Electric Journal*, March 1935, pages 120–3.) The technique of measurement has been developed in the past few years to a degree that these very short impulses can be recorded with good engineering accuracy.

The curves in figure 13 are for minimum flashover voltages. A family of constant time-lag curves could readily be drawn from figures 11 and 12.

The recent impulse data are obtained using the refined methods of measurement developed in the past few years. Furthermore, the effects of air density and humidity can now be accounted for. Hence, good checks have lately been possible between the different laboratories.

Particular mention is made of the early published data in the second paragraph of the paper and in references 13 and 19. To be sure, these early data are of qualitative interest but are obviously inadequate for the present design requirements. It is for these reasons that investigators have given so much attention in the past 5 years in an effort to establish reliable impulse data. These recent data are, therefore, of great practical usefulness as they relate to impulse waves of practical interest and to gap openings that correspond to the full practical range of transmission line voltage levels.

Recommended Transformer Standards

Discussion of a paper by H. V. Putman and J. E. Clem published in the December 1934 issue, pages 1594–7, and presented for oral discussion at the transformer symposium of the winter convention, New York, N. Y., January 22, 1935.

I. W. Gross (American Gas and Electric Co., New York, N. Y.): One objective of the committee, stated as "attempting to set up reasonable insulation levels for the design of transformers," is a worthy one, but since the transformer is only one link in the chain of insulation on a system, the question of whether the transformer impulse level here proposed by the committee will fit in with the broad problem of establishing insulation levels (a problem the joint N.E.M.A.-E.E.I. insulation co-ordination committee is now working on) should be carefully examined. Establishing insulation levels requires the co-ordinating of the various links of the insulation chain, and it does not seem obvious why the transformer is the starting point. On the contrary, it does seem reasonable that the transformer insulation strength, after system insulation levels have been set up, can be arrived at on the basis of the magnitude and characteristics of impulses which can reach the transformer, taking into account the type of protection used, that is, lightning arresters for both grounded and ungrounded systems, rod gaps, or even no protection whatsoever. This consideration logically leads to the conclusion that transformers in a given voltage class will require more than one voltage level.

The conclusion has been drawn by the authors that the 2 year experience on factory impulse testing on large power transformers "has demonstrated the practicability of commercial impulse tests." If the statement implies that all transformers tested have successfully withstood the impulse tests, and are giving satisfactory service in the field, supporting data will be most welcome to bear out this contention. In fact, it would be most desirable if the authors could give us, first, a summary of the number and kilovolt and kilovolt-ampere ratings of all transformers which have been impulse tested during the past 2 years, second, advise whether any of these transformers failed or showed distress during the test, third, inform us whether any failures of the transformers so tested have taken place after they have been placed in service, and, fourth, how long they have been in service under lightning conditions. An unspotted record over a sufficiently long period of time, showing that the transformers tested had successfully passed tests and had given perfect service in the field, would give considerable assurance that the present impulse test proposal is headed in the right direction.

The commercial impulse testing of transformers, which some 5 years ago was considered impractical by some closely connected with transformer designs, has now been established, but there is still a great deal to be done before we have the same assurance with regard to the impulse strength of transformers that we have on their 60 cycle strength. The commercial test work already done lays a foundation for extending the test procedure to give an indication of the insulation strength of a completely assembled transformer under more severe conditions than produced by minimum $1^1/_2 \times 40$ microsecond positive waves.

Regarding the revised impulse dielectric strength tests, it is suggested that a test be applied with "a wave having a crest at least 10 per cent greater than the minimum flashover voltage of the test gap." This statement in its present form is rather confusing and should be clarified.

Another point in connection with the test code relates to the polarity of the test wave. Assuming, as we have been told, that the insulation strength of the trans-

former is the same on both positive and negative impulses, the application of either polarity wave would indicate the strength of the transformer. However, data have been published showing that for a given rod gap some 15 per cent higher impulse voltage is required to break down the gap if the wave is negative than if it is of positive polarity. This means that the co-ordinating gap, so called, if used in service with the transformer would have to be set for approximately 85 per cent of the test gap to give the same protection against negative impulses of the same general shape as the test wave. With this consideration in mind I would like to ask the authors the interpretation which is to be placed on the gap spacings listed as "co-ordinating gap" in table I. It seems that a clear definition of "co-ordinating gap" would clarify the situation and would show just where this gap fits in the picture of insulation levels and co-ordination.

Again, if we are later to test transformers with negative impulses, since the test gap has some 15 per cent higher flashover for negative waves than for positive waves, the present proposed test gap spacings would have to be altered accordingly. The more consideration one gives to the gap as a standard of co-ordination the more it appears unsuited as an insulation level reference. Its value as a testing device is not questioned. This brings up again the question of establishing a standard for designating and measuring the impulse strength not only of transformers but also of other insulation.

It was pointed out as far back as 1930, at the time the lightning and insulator subcommittee of the power transmission and distribution committee was working to set up a standard of preferred test waves, that lightning strength should be expressed in terms "definitely expressive of lightning conditions," and that is in terms of volts and time and not in terms of gaps, insulators, or some other secondary standard.

One has only to refer to table III of the paper to see the difference between an expressed insulation strength in kilovolts and inches of rod gap spacing. The kilovolt values are definite, and can be co-ordinated with other insulation and other links in the insulation chain. Little can be said for the rod gap except that it is necessary to refer back to published curves or tabulated data to get the kilovolt value of each rod gap to co-ordinate its flashover value with other apparatus. It is believed that the sooner we can talk of impulse values of insulation in definite voltage values, the quicker we will put the entire insulation co-ordination, in its broadest aspect, on a firm foundation for solution.

It appears from table III that the proposed impulse flashovers for bushings are approximately 5 per cent higher than the test gap voltages for transformers. In other words, the proposal seems to set up a situation where the bushing is stronger than the safe limit of the transformer; that is, we are faced with a situation where the transformer is definitely not self-protecting in any sense of the word, unless it is proposed to use the factor of safety between the transformer tested strength and its ultimate strength to render the transformer self-protecting. I wish to ask the authors on what basis of co-ordination these proposed impulse flashovers for transformer bushings were arrived at, and how this basis compares with the situation which has existed for years on transformers which are now in service.

L. C. Nichols (Allis-Chalmers Mfg. Co., Milwaukee, Wis.): This paper shows that considerable progress has been made in establishing insulation levels. The last recommendation for impulse testing should be adopted instead of the first one proposed, as it can be determined better from the oscillograph records whether there has been a failure or not if the last impulse test is made with a full wave instead of with a chopped wave.

Table I referring to co-ordination gaps should be omitted, as we are standardizing tests and test gaps only.

There is a reasonably definite relation between the test gap and the low frequency dielectric tests. There also should be a fixed ratio between the impulse strength of the test gap and the impulse strength of the bushings. Bushings should have a 5 per cent greater impulse strength than the gap. These values should be the same for both power and distribution transformers.

If, on account of the size and importance of a transformer, it is desired to have larger bushings, then insulation of the next higher class should be used and the corresponding test gap, bushing, and low frequency test used.

If operating conditions are bad, severe lightning encountered, or if transformer protection requires the use of lightning arresters of larger size than normal as a result of overvoltage conditions prevailing, then insulation of the next higher class should be used.

If good operating conditions exist with good lightning protection provided and the neutral solidly grounded, then the next lower insulation class could be used.

Whatever insulation class is selected determines the test gap, bushing, and low frequency test. In other words, 3 standards of insulation are available. Bushings on transformers when shipped should always be provided with gaps of the same impulse strength as the test gap.

C. M. Foust (General Electric Co., Schenectady, N. Y.): In connection with this paper I would like to say something about impulse testing recommendations from the standpoint of the laboratory engineer who is called upon occasionally to make such tests. I will have to insist that the recommendations I have tried to follow in the past in performing tests have not been sufficiently clear to avoid possible incorrect procedure on the following points:

1. Is the test gap connected when the impulse is applied and does it spark over or not? This should be made clear for each impulse application. I do not believe that the phrase "minimum wave permitted by the test gap" as in test 1 of the proposed tests will be clear to all concerned. Just how a test gap permits or does not permit certain waves is left entirely to the imagination. In test 2 a wave is called for which is "just sufficient to flash over the specified test gap," and in test 3 "a wave having a crest at least 10 per cent greater than the minimum flashover of the test gap." Unless the sentence in the following paragraph reading "the test gap is connected directly to the ground" is taken as an instruction that the test gap shall be set at the specified gap of table I and connected in the circuit for tests 1, 2, and 3 these phrases are not specific. Probably the next paragraph beginning "without the test gap the transformers, etc.," does add to the clarity of what comes before. If so, my difficulty had already been recognized, and a way of overcoming it devised. A similar paragraph at the beginning reading "with the test gap connected and the spacing adjusted as per table I the transformer shall, etc.," would make the picture clearer from the beginning.

2. Is the impulse always applied to one high voltage terminal with the other terminal grounded? This should be made clear, so that there will be no temptation where both terminals are insulated to apply the impulse to both high voltage terminals.

3. When is power voltage to be applied? In test 5 I read as follows: "A wave as high as in test 3 or 4 but with means for maintaining the excitation voltage across all parts of the winding." The paragraph immediately following states: "All 5 of these tests are to be made with the transformer under full power voltage excitation and with impulse synchronized, etc." I am still at a loss to know just when to hold power voltage on the transformer. In this connection I would urge that some definite statement as to the important reason or reasons for holding power voltage on be incorporated in the recommendations. Such a statement would assist engineers in other fields to decide for themselves whether they required power voltage or not during impulse tests.

I note that the committee is hard at work on changes in the present test code. I would be happy to see the new recommendations very specific on points such as referred to above. I realize that the present paper is not supposed to be a standard in itself and that therefore my criticisms as applied to it may be little justified. However, it gives me the opportunity to call attention to uncertainties I have encountered in the present recommendations.

Overloading of Power Transformers

Discussion and authors' closure of a paper by V. M. Montsinger and W. M. Dann published in the October 1934 issue, pages 1353–5, and presented for oral discussion at the transformer symposium of the winter convention, New York, N. Y., January 22, 1935.

Herman Halperin (Commonwealth Edison Co., Chicago, Ill.): In considering the permissible short-time loads for transformers given in table I, it should be noted that, in those cases where the transformers feed into underground lines the relation of the short-time to the full-load ratings for cable may be quite different from the relations shown in the table.

In the A.I.E.E. rule for maximum allowable copper temperature for underground cable, there is no provision for high temperatures for short periods of time as there is elsewhere for some other insulations such as in transformers. Therefore, the establishment of short-time loads for cables has to be done either (1) at the expense of reducing the maximum allowable temperature for continuous loading and using the difference between this temperature and the maximum permissible by the A.I.E.E. rule to provide for special overloads, or (2) by permitting temperatures on the cable insulation in excess of those specified in the A.I.E.E. rule.

In the Commonwealth Edison Company the first procedure is being followed for 66 kv cables of the ordinary type, the maximum allowable temperature for steady load

being a few degrees below the maximum of 60 degrees centigrade set by the rule. As a result, as indicated, for example, in the accompanying table for the line out of State Line station the one hour overload rating for the cable for recurrent loads is 5 per cent larger than the same rating for the transformer, while for emergency loads that may occur every few years the transformer rating is considerably larger than the cable rating for one hour overloads.

Ratings of 100,000-Kva 66-Kv Transmission Apparatus in Chicago in Summer

	Apparatus Ratings in Kva	
	Transformer	Cable
Full load	100,000	96,000
One hour overload,		
Recurrent	105,000	110,000
Emergency	140,000	110,000

For about 10 per cent additional cost, oil filled cable may be used instead of 66 kv cable of the ordinary type covered by the table, and in such case the one hour emergency rating for use in Chicago conduits would be about 180,000 kva, which is more than the transformer rating. It is doubtful for the example given whether we could or would try to feed 140,000 kva or 180,000 kva into the 66 kv system even if the cable could safely stand the load. For most of our system, however, the transformers feed into a bus and the 66 kv lines come off the same bus, so that in rare instances some advantage may be taken of the high emergency ratings of such transformers. Normally these transformers operate appreciably below their full load rating, with the result that the copper temperatures at the time of daily system peak are, roughly, from 15 to 60 degrees centigrade or more below the permissible maximum of 105 degrees.

By decreasing the magnitude of the overloads on its distribution transformers, so that in general the transformers operate over a period of only a few months at about full-load rating or 10 to 20 per cent over full-load rating, the company has practically eliminated failures in these transformers from overloads and high temperatures.

Our operating engineers indicated a few years ago that from their standpoint the most efficient way of rating cables was to establish full-load ratings in such a way that the lines would have ample carrying capacity for normal conditions when all lines and equipment are in service, and establish overload ratings to take care of those occasional situations when a line or piece of equipment is out of service. This arrangement has proved quite satisfactory.

For 3-conductor 12-kv cables, we have established, for one special group of lines, an emergency rating for 2 hours following full load of about 10 per cent over full-load rating in contrast to the 25 per cent excess permitted in table I of the paper for emergency loads on transformers for 2 hours.

There are a number of factors not covered by A.I.E.E. rules or in the A.E.I.C. cable specifications, such as cable movement, sheath stretching, void formation, and maximum allowable copper temperature for short periods, which must be taken into account in the establishment of special ratings for cables.

For 66 kv cables of the ordinary type, we have found some lots which have been in service for a number of years and removed for various reasons to have suffered no appreciable deterioration even after operating at about the maximum allowable temperature permitted by the A.I.E.E. rule. In contrast with this, we have the implication in the article by the authors and in the report of experimental data in the paper by L. C. Nichols that, when transformer insulation is operated at the maximum allowable temperature for continuous operation and at excess temperatures for short periods of time, the insulation would have a relatively short life. Nichols gives a life of only $1^1/_8$ years for transformer insulation operated at 105 degrees centigrade. This temperature is 20 degrees and 30 degrees, respectively, above the maximum allowable temperatures for low voltage impregnated paper insulation and varnished cambric insulation when in cables according to the A.I.E.E. rules. For higher voltages, the differences are larger. Even after allowing for the differences in the duty on these similar fibrous materials used in transformers and in cables, apparently there is a smaller factor of safety in the allowable temperature limits and allowable overloads established for transformer insulation than for cable insulation and, when considering the transmission units consisting of transformers and underground lines, utility engineers should keep this point in mind.

L. C. Nichols (Allis-Chalmers Mfg. Co., Milwaukee, Wis.): This paper gives some valuable information regarding the overloading of power transformers. It is interesting to note that the emergency overloads use up $^1/_4$ of one per cent of the life for each overload and the recurrent overloads use up 1/1,000 of one per cent of the life for each load.

It might be well to reconsider the allowable overload of one per cent for each degree that the ambient temperature is below 30 degrees centigrade. If a transformer will carry 100 per cent load in a 40 degree ambient, it can carry more than 100 per cent load when the ambient is below 40 degrees but above 30 degrees without exceeding 105 degrees at a hot spot. The present rules should be changed to allow one per cent overload for each degree the ambient is below 40 degrees. Another way of expressing permissible load would be to set up a tabulation showing permissible load and time of load according to actual oil temperature without the temperature of the windings exceeding a hot spot temperature of 105 degrees. The tabulation should show permissible loads following full load and following no load. The tabulation would be approximately as given in table I of this discussion.

The oil temperature should not be allowed to exceed 90 degrees centigrade under any conditions, and when full load is carried on the transformer, the oil temperature should be limited to 80 degrees. When the oil temperature is below 80 degrees increased loads can be carried as shown in the tabulation.

The allowable loads can better be determined from oil temperature than from ambient temperature.

Basil Lanphier* (American Gas and Electric Co., New York, N. Y.): Although I am a member of the transformer subcommittee, my first acquaintance with the matter contained in this paper, which is presented in the name of the transformer subcommittee, was through the pages of Electrical Engineering. I want, therefore, to dissociate myself completely from any official connection or any official sponsoring of the matter contained therein.

The statement in the first paragraph that "the sole purpose of these standards is to establish a standardization of design and test" may express the designer's and manu-

* Deceased; see page 801.

Table I—Permissible Load on Transformers With Hot Spot Temperature of 105° C.

Following Full Load	Oil Temperature, Degrees Centigrade										Per Cent Loss in Life
	80	75	70	65	60	55	50	45	40	35	
Per cent load, 1 minute	100	160	200	235	265	290	315	338	360	380	0.0002
Per cent load, 2 minutes	100	136	165	190	210	229	247	263	278	293	0.0004
Per cent load, 3 minutes	100	127	151	171	190	206	220	233	246	258	0.0006
Per cent load, 4 minutes	100	122	144	161	177	191	205	218	230	241	0.0008
Per cent load, 5 minutes	100	120	139	155	170	183	196	207	218	228	0.0010
Per cent load, 10 minutes	100	117	132	145	157	168	180	189	199	208	0.002
Per cent load, 20 minutes	100	114	128	140	152	162	173	182	191	200	0.004
Per cent load, continuous	100	114	128	140	152	162	173	182	191	200	

Following No Load	Oil Temperature, Degrees Centigrade										Per Cent Loss in Life
	80	75	70	65	60	55	50	45	40	35	
Per cent load, 1 minute	230	244	272	300	322	345	366	387	410		0.0002
Per cent load, 2 minutes	160	185	206	225	242	260	276	291	305	319	0.0004
Per cent load, 3 minutes	137	157	177	194	210	225	239	251	263	274	0.0006
Per cent load, 4 minutes	124	144	161	177	192	206	218	230	240	261	0.0008
Per cent load, 5 minutes	117	136	153	168	181	194	206	217	228	237	0.0010
Per cent load, 10 minutes	104	121	135	148	159	170	181	191	200	209	0.0020
Per cent load, 20 minutes	100	114	128	140	152	163	173	182	191	200	0.004
Per cent load, continuous	100	114	128	140	152	163	173	182	191	200	

Oil temperatures must not be exceeded. Per cent loss in life is the per cent loss for each time transformer is loaded. Twenty minute interval should elapse between each overload.

facturer's viewpoint. In the eyes of the operator and purchaser, however, the standards are looked upon as a guide toward obtaining transformers that will operate with a minimum amount of trouble when carrying their rated load continuously for an indefinite number of years.

In support of the foregoing thought, I quote paragraph 121 of A.I.E.E. Standards No. 13—"continuous duty is a requirement of *service* that demands *operation* at substantially constant load for an *unlimited period*." Further, paragraph 150 defines rating as "a rating of a machine, apparatus, or device is an arbitrary designation of an *operating* limit."

A second point in the authors' paper that should be amplified and supported by the details of their laboratory tests is the statement that "the rate of mechanical deterioration of fibrous insulating material doubles approximately for each 8 degree centigrade increase of temperature." In support of this conclusion, reference is made to V. M. Montsinger's paper "Loading Transformers by Temperature," A.I.E.E. TRANSACTIONS, volume 49, April 1930, pages 776–90.

From a careful review of this 1930 paper, we find that tests were made on black and yellow varnished cloths for a period of 68 weeks to determine the decrease in tensile strength when subjected to temperatures of from 90 to 100 or 105 degrees centigrade in both air and oil.

It is our thought that varnished cloths constitute a very small part in transformer insulation and that further research should be conducted, particularly upon oil which is relied upon for the larger portion of the insulation, and upon the solid materials, such as "herkolite," which are used for the coil forms and other major insulation.

Decrease in tensile strength of materials in a stationary device such as a transformer winding we do not believe should be made the major factor in determining the rate of aging of the entire transformer. As long as the machine is undisturbed, the only requirement of the fibrous insulation on the turns is to give spacing and separation. Oil in good condition will supply the required insulation.

The useful life of power transformers can best be determined, we believe, by an analysis of failures in actual service. A survey of the records of our companies discloses that during the past 10 years about a dozen failures have taken place in large power transformers, and with one exception, these failures have been definitely diagnosed as caused by lightning.

The one exception mentioned above resulted from a failure of the protective devices to isolate a transformer that was supplying energy to a solid short circuit.

By proper application of the lightning arresters that are now available, together with the co-ordination of line insulation, installation of ground wires, etc., we believe that we have definitely corrected these conditions and eliminated lightning as the major cause of continued failures on our large power transformers.

It seems to me that the authors are definitely admitting that for years they have been selling equipment under definite guarantees and are now beginning to have doubts as to whether those guarantees should be taken as seriously as most purchasers have taken them. Disregarding many of the questions of business responsibility and business ethics that this attitude raises, it would seem to me that it is imperative not only that the manufacturers do something to improve the present insulating materials to withstand the present A.I.E.E. standard temperature limits, but that an effort be made to raise the present operating temperature limit of 95 degrees so that the cost of transformers may be substantially reduced. Whether this takes the form of new insulating materials to replace varnished cambric, paper, and other solid insulating materials used in transformers, new liquid dielectrics, or new methods of cooling, is a manufacturer's research problem. There is one thing, however, that the manufacturers and their engineers may be certain of—the need for lower cost equipment is imperative. It remains to be seen whether the manufacturers with the most experience in this field will rise to this demand.

E. A. Church (Edison Electric Illuminating Company of Boston, Mass.): It might be stated that the 2-hour overload capacities for recurrent loads listed in table I check very closely the results we have obtained for 24-hour period load cycles. It might be well to define more clearly the term "recurrent loads" before this standard is adopted by the A.I.E.E. for loading of transformers. Does recurrent mean repeated daily, weekly, or what period? The results we have obtained indicate that they might be repeated daily without decreasing the life of the transformer to any appreciable extent.

V. M. Montsinger (General Electric Co., Pittsfield, Mass.) and **W. M. Dann** (Westinghouse Elec. and Mfg. Co., E. Pittsburgh, Pa.): Lanphier questions the validity of the 8 degree rule on the basis that it was based only on tests on varnished cloths as reported in the 1930 paper on "Loading Transformers by Temperature" by V. M. Montsinger. Figure 8 in this report gives the results of tests made at the Massachusetts Institute of Technology on cable paper. This shows that the 8 degree rule holds for cable paper as well as for varnished cloth. Cable paper is used quite extensively for turn insulation in transformers.

Lanphier further states that his company has had no failures from deterioration but presents no data to show that any of the transformers involved were operated at long periods at temperatures approaching 105 degrees centigrade hot spot. If he has data of this sort it would be valuable to have it presented before the Institute.

The Institute standard prescribing a temperature rise of 55 degrees centigrade at full load was established many years ago to define the size of a transformer having a given rating, and we find in Standard No. 1 the statement, in capital letters, that this temperature rise was established *for the purpose of assigning a rating.* It was coupled—rightly or wrongly—with a *maximum* ambient temperature of 40 degrees and the whole plan constituted "an *arbitrary* designation of an operating limit," to quote from Lanphier's remarks with just a little change in the emphasis. This scheme of rating is quite a different matter from a specification that the transformer will operate continuously in a 40 degree ambient for a long period of time with no measurable deterioration of the insulation. However, experience has shown that this standard of rating has been satisfactory for usual operating conditions and that trouble has been encountered only in relatively few cases with unusual conditions. The differences between standards for rating and operating practice are on the whole rather generally appreciated.

Lanphier states that he does not consider the tensile strength of the insulation a good measure of the deterioration in a transformer. There are, broadly speaking, 2 forms of deterioration in oil immersed transformers; the first being deterioration of the solid insulations, and the second being deterioration of the oil. Either of these, if carried to extremes, will ruin a perfectly good transformer. It has been found from careful laboratory investigations that tensile and bending tests are the most satisfactory measures of deterioration in the solid materials. Dielectric tests are practically useless for this purpose since the dielectric strength remains practically constant until the insulation is completely ruined when the puncture strength falls off suddenly to practically nothing. In large transformers in particular it is important that the mechanical strength of the insulations be maintained to prevent disruption and electrical failure as a result of magnetic forces.

Nichols suggests that the present A.I.E.E. rules on operating recommendations be changed to allow one per cent overload for each degree the ambient is below 40 degrees instead of one per cent for each degree that the ambient is below 30 degrees. It seems to us that he is not consistent in advocating this change. For instance, he states in his paper on "Effect of Overload on Transformer Life" that if the transformer is operated at rated load continuously in a 40 degree ambient, the life will be very much below that normally expected of a transformer. Everyone knows, of course, that transformers seldom operate continuously under these extreme conditions and it is for this reason that transformers under average operating conditions have given satisfactory service. Now Nichols is proposing that the rules be changed to permit sufficient overload in low ambients to simulate the condition of a transformer operating at rated load continuously in a 40 degree ambient. As a matter of fact, by permitting the one per cent rule to start at 40 degrees it would be possible and much more likely to result in continuous operation at 105 degrees hot spot than it is possible to maintain 105 degrees under rated load conditions in a 40 degree ambient. For this reason we are somewhat surprised to see that Nichols proposes to start the one per cent per degree overload at 40 degrees instead of 30 degrees.

Halperin in comparing the overload capacities of cables and transformers shows the transformer at a disadvantage on recurrent overloads but in doing so states that his full-load rating of the cable was arbitrarily reduced before making the comparison. According to his own statements, the transformer would have a 5 per cent, one-hour recurrent overload rating, whereas the cable would have a zero overload rating

and must, therefore, be underrated for the normal application. A still greater advantage for the transformer would be shown if it also were underrated for normal load. The mere fact that it is necessary to underrate a cable and not a transformer shows the advantage of the cooling by oil circulation that is used in transformer designs.

Church raises the point as to the precise definition of a recurrent load. The definition of a recurrent load given in the paper states that it is one regarded as an occasional occurrence with steady state temperature conditions restored before repetition. This would permit the loads to be repeated at least once a day as this will give time enough for the temperature to be restored to the value preceding the overload.

Effect of Overloads on Transformer Life

Discussion and author's closure of a paper by L. C. Nichols published in the December 1934 issue, pages 1616–21, and presented for oral discussion at the transformer symposium of the winter convention, New York, N. Y., January 22, 1935.

W. M. Dann (Westinghouse Elec. and Mfg. Co., E. Pittsburgh, Pa.): The 8 degree rule, which is the foundation of Nichols's ideas about the life of transformer insulation, seems to have enough authority behind it to justify using it in the way that he has done. If we can accept it as a fact that it holds true over a range of temperatures corresponding to time periods from a few seconds to a number of years, then with the relation between deterioration and temperature definitely fixed, all that is necessary in order to create a complete schedule of transformer life under all temperature conditions is to be sure that we select the proper starting point as the basis of deterioration and temperature.

As I understand it, Nichols has selected for his starting point a life of 5 years for insulation under oil at 90 degrees centigrade. Based on this starting point, the life of a transformer operating continuously at 55 degrees rise above an ambient temperature of 40 degrees works out to be $1^1/_3$ years. I suspect that among those who have done research work with transformer insulation there will be a number of different opinions about the validity of this starting point and of the results that come from it.

I should like to point out the importance of this starting point. When we make temperature runs on transformers, it is sometimes difficult to duplicate temperatures on identical tests within 2 or 3 degrees. Suppose that instead of the starting point of 90 degrees centigrade we were to adopt a temperature only a couple of degrees higher. Then all the curves and tabulations shown in this paper would be wrong to the extent of 25 per cent, and immediately 4 months would be added to the $1^1/_3$ years which is given as the life of a transformer operating continuously at 55 degrees rise above 40 degrees. I mention this simply to point out that a very small difference in the temperature of the starting point makes a large difference in all the calculated results.

My idea of this paper is that the author has contributed a *method* which is ingenious and which has a lot of merit. Nevertheless, I am afraid that it is not at all clear that we can accept his conclusions as a definite and precise guide for overloading transformers in service.

J. E. Clem (General Electric Co., Schenectady, N. Y.): The subject of overloading of transformers has received a great deal of attention by the transformer subcommittee during the past 3 or 4 years. When this subject was first introduced into the subcommittee by the publication of 2 articles entitled "Loading Transformers by Temperature," by V. M. Montsinger, and "Operating Transformers by Temperature," by W. M. Dann and presented at the A.I.E.E. winter convention in January 1930, the subcommittee considered 2 general methods of overloading transformers. One method was to base the magnitude and duration of overloads on the mechanical deterioration of the insulation. The other method was to assign definite overloads in terms of the rating for different durations of time.

At the time the subcommittee undertook this work it had available a large amount of data on the effect of temperature on the aging of insulation (given in Montsinger's paper). The suggested method as now proposed by Nichols was carefully considered but it was not felt to be either a safe or practical method to use in setting up standards.

The subcommittee finally decided to recommend conservative overloads in terms of the name-plate rating for various durations of time as given in the subcommittee's report by Montsinger and Dann.

Now that Nichols has suggested the method of governing overloads by the deterioration of insulation, it becomes necessary to point out some of the principal reasons why the transformer subcommittee did not recommend this method. Up to the present time we have had very little experience in operating transformers under heavy overload conditions. In fact, until about 1925 the A.I.E.E. rules stated that "the name-plate rating of a transformer must not be exceeded whatever be the ambient." Although A.I.E.E. Standards No. 100 has permitted for some 3 or 4 years 30 per cent continuous overload for self-cooled transformers and 25 per cent continuous overload for water-cooled transformers coupled with low ambient temperatures, the final temperatures have not exceeded about 85 to 95 degree centigrade. Consequently, we really have had no experience in overloads that produced high temperatures for definite periods of time. During short circuit the duration of the time is very indefinite. The same can be said of grounding transformers which are expected to stand 160 degrees for one minute.

Even under conservative methods of loading transformers, experience has shown that some transformers have extremely long lives while others operating under severe conditions have relatively short lives. The reasons for this very large difference are the many factors which enter into the life of a transformer such as mechanical vibration, variation in quality of insulating materials, formation of sludge on the windings, effect of temperature in decreasing the dielectric strength momentarily—all these in addition to the mechanical deterioration of the insulation during the duration of the high temperature. It should be recognized that one cannot impose severe overloads on a transformer and expect it to have the length of life of a transformer that is not called upon to carry severe overloads.

The question, of course, is an economic one and in some cases the operator may be willing to sacrifice some of the life of the transformer in order to carry him over an emergency condition. However, if one expects a transformer to last from 20 to 30 years, which is not unusual, it cannot be expected to carry extremely heavy overloads at frequent intervals. When the transformer subcommittee was considering this method, calculations soon indicated that extremely heavy overloads could be carried for short periods with a very small amount of mechanical deterioration of the insulation. Having had no experience along this line it was not felt safe to recommend a method which indicated that such heavy overloads could safely be carried. It was recognized, however, that under emergency conditions one would be justified in permitting overloads considerably in excess of recurrent overloads; that is, overloads which are deliberately imposed on the transformer at frequent intervals. For this reason the subcommittee recommended permitting higher overloads for emergency conditions than for recurrent conditions.

In the final analysis it comes down to the fact that one cannot get something for nothing. If you impose heavy overloads on transformers you must expect a shortened life and if conservatism is not used the life may be very much shorter than that indicated by adding up the per cent deterioration of the insulation alone.

It was principally for these reasons that the transformer subcommittee abandoned the method now suggested by Nichols and recommended the method given in the companion paper. I strongly recommend that for the present we give the more conservative method a trial. Later, after we have obtained more experience, it may be possible to increase the loads above the values recommended by the subcommittee.

W. H. Cooney (General Electric Co., Pittsfield, Mass.): The author has approached the problem of transformer overloading by an interesting and ingenious method, but I cannot agree with his paper in 2 aspects: first, the data which he presents; and second, the dependability of aging of insulation as a sole basis for determining permissible transformer overloads.

The subject of aging, and its application to transformer loading, was covered quite fully in V. M. Montsinger's "Loading Transformers by Temperature" (A.I.E.E. Transactions, volume 49, April 1930, pages 776–90), in which he presented for the first time the so-called 8 degree centigrade rule. This rule is to the effect that for each 8 degree increase in temperature, the rate of deterioration of insulation is doubled, and it is interesting to note that figure 1 of Nichols shows the same change of rate of deterioration as Montsinger's figure 11. A wide discrepancy is evident in the life at 105 degrees, the previous paper showing 7 years, this one $1^1/_3$ years. This is a ratio of over 5 to 1, holding

throughout the curve. Other than to state that after 5 years in oil at 90 degrees insulation is "exceedingly brittle," Nichols does not describe the type of mechanical test on which his curve is based. Montsinger used both tensile and folding, and if Nichols used some other form of test, this may explain part of the wide difference.

The value of the varying safety factor of figure 1 is doubtful, for at 250 degrees centigrade the 5 to 1 discrepancy I mentioned becomes 50 to 1. From another viewpoint, at 250 degrees the calculated life is based 10 per cent on data and 90 per cent on an arbitrary factor. If some safety factor is considered necessary it should be uniform, or preferably the safety factor should be applied to the temperature calculations.

Figure 1 also shows the danger of extrapolating data of this sort. A life of 100 years at 55 degrees centigrade and especially of 1,000 years at 30 degrees seems to be extrapolating to an unreasonable extent.

Whether the aging of insulation alone is a dependable guide for operating transformers is a question open to discussion. In Montsinger's paper he stated "It is doubtful if the actual life of a transformer can ever be determined, even by the most carefully conducted laboratory test, due to the lack of a proper criterion by which to judge whether an insulation has reached an unsafe degree of deterioration."

I have called attention to the wide difference between the 2 sets of data. In addition there is a large variation of "life" among the various transformer insulating materials and also with the treatment applied to a given material, although in general the 8 degree rule is followed. Since a transformer is a complex combination of materials, any general aging rule is bound to be a very crude approximation.

The question of dielectric strength cannot be ignored. It seems to have been proved that even exceedingly brittle insulation has practically its original dielectric strength provided it is not disturbed. (That is, aging is primarily a loss of mechanical strength.) However, the dielectric strength of insulation decreases with increasing temperature, and tests have shown that with an elevation in temperature of 100 degrees centigrade untreated insulation suffers a loss of 50 per cent of its dielectric strength. Although the original dielectric strength is regained after cooling, it is evident that a transformer is quite vulnerable to overvoltage during a heavy overload.

Insulation aging is not the only factor which may shorten the life of a transformer. At prolonged high temperatures the oil, especially in open transformers, may become oxidized long before serious aging of the insulation occurs. There is also oil within the windings and a thin film of oil in contact with the surface of windings which may have a temperature equal to or approaching that of the copper during severe overloads. Undoubtedly these local oil temperatures will have a deleterious effect on the life of the oil. Nichols does not even consider these factors.

One of the principle fallacies in using insulation aging as a basis for loading is the premise that all the life may be used; that, for instance, a load which uses 10 per cent of the life may be applied 10 times. This ignores the progressive mechanical weakening. That is, when 50 per cent of the life is gone, it should be considered that the transformer insulation is only one half as strong as when new and it may fail under the mechanical stresses of a short circuit which it could easily have withstood in its original condition. A simple analogy is that of a rope, used to lift a given load, which becomes half worn through in a year. It cannot be assumed that it will last another year, for it may break the next time it is used.

Moreover, the amount of aging which a transformer can experience and still withstand short circuits varies greatly with the type of conductor, turn insulation, treatment, general winding design, etc. These factors will influence through a wide range the degree to which the loss of original life may be carried before transformer failure.

Still another factor is the type of overload which may be applied. Aging data may indicate a given life for a transformer with (a) sustained overloads not greatly exceeding rated load in value or (b) a large number of heavy overloads, each of comparatively short duration. The transformer which is never subjected to appreciable overloads may approach the theoretical life before failure occurs; the transformer which is subjected to severe overloads will probably fail much sooner because the vibration and stresses of heavy overloads will tend to hasten mechanical failure of the insulation between various parts of the windings.

Manufacturers and operators know of cases of extremely short and extremely long transformer lives. Some transformers have operated for over 30 years. Others under very severe conditions have lasted only a few. That is, the extremes of life have been observed, with the obvious conclusion that the more a transformer is overloaded, the shorter is its life. Considering the wide variation of data and the many factors which must be considered, aging alone does not appear to be a reliable guide for loading. Rather, it seems desirable to follow recommendations based on general service experience, such as those proposed by Montsinger and Dann for the transformer subcommittee ("Recommended Transformer Standards," ELECTRICAL ENGINEERING, October 1934, pages 1594–7).

However, the paper by Nichols is of value in promoting at this time a full and frank discussion of a subject of interest to every transformer designing and operating engineer.

Philip Sporn (American Gas and Electric Co., New York, N. Y.): I wish to comment upon conclusion 4 of this most interesting and, in some respects, astonishing paper. This conclusion states, "If a transformer is loaded at a constant load 24 hours a day in a 40-degree ambient temperature, then a transformer rated $^1/_3$ larger than the load should be used." The natural corollary to this conclusion is, of course, that it is *not safe* to operate transformers of present American design and manufacture at a temperature maintained continuously at 95 degrees centigrade.

Further, where such operating conditions have been called for and a transformer rated only up to the load was purchased, then the presumption is that a transformer too small for the load has been purchased.

Contrasted to this conclusion, I would like to quote a statement made by E. T. Norris, chief designer of Ferranti, Ltd., England, in his paper presented before the A.I.E.E. in June 1929, entitled, "Safe Loading of Oil-Immersed Transformers" (A.I.E.E. TRANSACTIONS, volume 48, Oct. 1929, pages 1206–12). He stated, "It has become general practice for operating engineers to consider the standard rating as being the maximum safe rating under normal working conditions. Transformers larger than is necessary are, therefore, installed." These are 2 views of the chief designers of 2 outstanding manufacturers, which most certainly do not agree at any point.

There is another most vital point that needs to be considered. A.I.E.E. Standards No. 13 specify as usual service conditions that the temperature of the cooling medium shall not exceed 40 degrees centigrade, and that a temperature rise of 55 degrees for continuous loading shall not be exceeded. The summation of these 2 limiting conditions results in a total temperature of 95 degrees. I am sure that I express the opinion of most designing and operating engineers when I state that they have all for many decades been specifying, buying, and installing transformers on the basis that if the transformers were operated at full load at those temperatures their life would not only be comparative with that of other electrical equipment, but considerably longer, in view of the static nature of the device. Our own experience would indicate that we have had considerable justification for that belief.

If it is the intent of Nichols in presenting this particular viewpoint to scare a great many users into replacing transformer equipment, or if his intent is more subtle, I for one must admit not being able to penetrate the subtlety of the intent. Certainly from a standpoint of guarantee contained in A.I.E.E. Standards there is no warrant for an attitude implied in the paper, although there may be ample warrant for a belief that insulation does not last indefinitely and that its life is affected by the extent to which it is subjected to high temperatures. Further, I do not believe that the author's experience with his own transformers, with the performance of some of which we are acquainted, is such as to warrant an opinion on his part that they are subject to the hazards of life indicated by his data. I do believe, too, that where such situations do exist it is imperative that the designers concerned do something toward correcting these conditions and seeing that the equipment is brought up to the point where it will meet A.I.E.E. standard guarantees under the conditions prescribed and allowed for by these guarantees.

H. V. Putman (Westinghouse Elec. and Mfg. Co., Sharon, Pa.): I have been very much interested in reading this paper, which deals with a subject which those of us engaged in transformer work have had to consider. He arrives at a practical answer to a number of practical questions, but there are one or 2 questions which I think may well be raised before accepting completely his conclusions:

First, I would like to ask whether the curves shown in figure 1, which show the life of insulation in oil at various temperatures, are based completely on experimental data or whether they are drawn by assuming the validity of the so-called "8 degree law," and determining the constants to be used in this formula in order to make it check 1 or 2 experimental points. Was there sufficient experimental data obtained to support the validity of the 8 degree law, which in previous experiments has been found to be approximately correct?

Second, I would like to point out that the deterioration as indicated by figure 1 is largely an oxidation process, at least up to temperatures of the order of 150 degrees centigrade, so that the rates of deterioration may be greatly affected by the conditions under which the experiment is performed. Some years ago we made tests on transformer insulation at the research laboratory in an inert air atmosphere such as is present in an "inertaire" transformer. Over a period of 2 years, at a temperature in excess of 105 degrees, there was no measurable deterioration of the insulation, mechanical strength and brittleness of the insulation being the characteristics examined for deterioration. I am therefore not prepared to accept the author's fourth conclusion to the effect that a transformer cannot carry its full load at 40 degrees ambient temperature with a 55 degree rise. I am certain that a transformer in an inert atmosphere cannot only carry this load continuously but can carry it without measurable deterioration.

The next question I would like to raise has to do with the life of the insulation. When is the life completely used up? I think there is room for consideradle speculation on this point. Recently we made a distribution transformer experimentally without gum treatment for tests at high temperatures. As a final test we operated it at 175 degrees copper temperature for approximately 2 days. According to curve 1 of the paper, the life of the insulation at this temperature would have been about one day. At the end of 2 days there were no external signs of distress or deterioration and the transformer was given its regular dielectric test a second time and was then tested to destruction with impulse voltages. Its impulse strength was found to be normal, so that the insulation appeared to be as good as ever from a dielectric strength standpoint. We then sawed a large section out of the winding and opened it in the middle to expose the innermost layers. Considerable roasting of the insulation in the middle of the winding was immediately apparent and the discoloration extended from the center to within an inch or so of the outer edges. Physically the insulation was intact, but it had lost much of its mechanical strength because one could scrape off with the finger nail the cambric and paper insulation exposing the bare copper. Should we say that the life of the insulation in this transformer was completely used up? My own personal opinion is that it might still have delivered the full life of useful service in spite of the fact that it had been operated approximately twice as long as Nichols' curves would indicate. My point is that insulation deterioration at best is very intangible and indefinite, and when we proceed to define the life of insulation in terms of days, hours, and minutes as Nichols has done, we should keep this in mind.

My next point has to do with the practical application of permissible short-time overloads. Power transformers as a rule are provided with hot spot temperature indicating equipment and the amount of load can in many cases be adjusted by the load dispatcher, so that given a knowledge of the permissible short-time overloads it is physically practicable to use this information in the operation of the transformers. When we come to distribution transformers the problem is different. It isn't the load dispatcher, but it is Mrs. Jones or Mrs. Brown or somebody else who determines how much load the distribution transformer shall carry, so that the problem of operating distribution transformers by temperature becomes one of utilizing a protective device in the circuit which can be made to follow the temperature characteristics of the transformer winding. This is a problem in which I have personally been very much interested, and as many of you may know, the circuit breaker which we utilize in our "CSP" transformer is so arranged that it will function to trip the transformer from the line; not at any particular overload, not at any particular oil temperature, but at some particularly dangerous copper temperature.

Originally we thought the maximum copper temperature should be between 105 and 110 degrees and our breakers were adjusted to limit the copper temperature to this value under all conditions. However, we soon found that it was perfectly possible to so design the thermal elements of the breaker and to so make the adjustment that higher copper temperatures would be permitted for relatively short times. For example, data of Nichols and our own experiments show that it is quite all right for a transformer to withstand for a few minutes a copper temperature as high as 175 or 200 degrees, whereas if the overload is to endure for an hour the maximum copper temperature should be 25 or 30 degrees lower. We have found that it is practicable to adjust breakers on this basis, permitting a very high temperature for very short times and lower temperatures for correspondingly longer periods. We are thus able to make a practical application in distribution transformers of the important conclusion of the paper that transformers can withstand for short periods of time surprisingly high copper temperatures without appreciable loss in life.

V. M. Montsinger (General Electric Co., Pittsfield, Mass.): The curves in figure 1 indicate that the life of insulation at 105 degrees centigrade is $1^1/_3$ years. The curve given in figure 11 of my paper "Loading Transformers by Temperature" (A.I.E.E. Transactions, volume 49, April 1930, pages 776–90) indicates a life of 7 years at 105 degrees.

In reading Nichols's paper I gather that his tests were made by immersing single layers of insulation in oil in such a way that both sides of the insulation were exposed to the oil. I found that there is a considerable difference in the life of insulation depending on whether each side is exposed to the oil or whether the sheets are on the inside of a packet, more or less protected from the oil. I am wondering if this large difference in our results cannot be accounted for by the difference in the methods of making the aging tests.

As a matter of fact, most insulations in a transformer, except the outside layers, are protected from the oil to a certain extent. For this reason I believe Nichols' curves are too pessimistic when used in determining the actual life of a transformer.

I would like to ask the author if he has any data to support the 8 degree rule, which was given and supported by data in my 1930 paper. If the author has such data it would be interesting to know how closely it supports this rule.

Lynn Wetherill (General Electric Co., Pittsfield, Mass.): The writer does not share the author's belief that overheating transformers involves no danger except embrittlement of insulation, but these comments are limited to assumptions used in calculation of loss of life from short time overloads, as shown in table I of the paper.

It appears that the rise of hot spot over average winding temperature, which is 10 degrees centigrade at continuous full load, is assumed to increase in proportion to average winding rise over oil. This accords with usual practice.

It further appears that in calculating the amount of life used in short time overloads Nichols has assumed the temperature to rise instantly to the maximum value when the load is applied, and to return instantly to normal when the load is removed. This may be substantiated by checking the values in table I, and is illustrated by the fact that the loss of life shown for 24 hour overloads is independent of the preceding load. Thus 125 per cent load for 24 hours in a 40 degree centigrated ambient is said to use 6 per cent of the life regardless of the initial temperature.

Consider 2,000 per cent load for 5 seconds after full load in a 20 degree centigrade ambient, for which Nichols obtains 26.5 per cent loss of life. The copper reaches maximum temperature in 5 seconds, but requires 20 minutes to cool, with the result that practically all of the aging occurs after the overload has been removed. Assuming, with Nichols, that the maximum temperature is 250 degrees, the loss of life during the overload is less than 1 per cent, but approximately 40 per cent is lost after the overload has been removed.

Nichols states that the resistance is assumed constant at the 75 degree centigrade value. The magnitude of the error involved in neglect of change in resistance can be best appreciated by considering the accompanying table I, which shows the components of the ultimate rise for 150 per cent load in 40 degrees ambient.

Calculation is based upon the same transformer characteristics used in the paper. If resistance change is neglected a hot-spot temperature of 164 degrees centigrade is obtained, which checks Nichols' results fairly closely. If resistance change is considered, 193 degrees is obtained; this is 29 degrees higher.

In table I Nichols indicates that a transformer would operate 24 hours at 150 per cent load in 40 degree centigrade ambient, despite having a hot-spot temperature near 190 degrees most of the 24 hours.

Consider the effect of resistance change on temperatures resulting from very short time overloads. In figure 9 Nichols shows 120 degrees winding temperature rise over oil for 1,000 per cent load maintained 23 seconds. Assuming an initial temperature of 75 degrees centigrade, and 10 per cent eddy loss at 75 degrees, a proper allowance for resistance change indicates a winding rise over oil of 161.5 degrees instead of 120 degrees.

The method of calculation which Nichols uses is subject to large errors when applied to the rise of winding over oil for overloads lasting 5 minutes or less, even though resistance change is considered. For such overloads a calculation based upon the fraction of the ultimate rise appearing at a certain time is not only inaccurate but is physically absurd when the fictitious ultimate rise is on the order of 1,500 degrees centigrade. For overloads of this nature, the calculations should be based on the current density and the eddy loss (the formula is given in A.I.E.E. Standards No. 13).

Consider the case of 200 per cent load for 30 minutes following full load in a 40 degrees centigrade ambient. For this condition Nichols' curves indicate the following temperature (degrees centigrade) and resultant loss of life:

Ambient temperature	40
Oil temperature rise over ambient	52
Average temperature winding rise over oil	60
Hot-spot temperature rise over average winding	40
Total temperature rise	192

The resultant loss of life is indicated by

$$\frac{4.8 \times 30}{600} 100 = 24 \text{ per cent}$$

Nichols gives 3 per cent loss of life in table I. Perhaps he failed to include the 12 degree centigrade increase in oil temperature.

However, if resistance change is considered, the following results (degrees centigrade) are obtained:

Ambient temperature	40
Oil temperature rise over ambient	52
Average temperature winding rise over oil	78
Hot-spot temperature rise over average winding	52
Total temperature rise	222

The calculation of the loss of life is

$$\frac{7.2 \times 30}{50} 100 = 430 \text{ per cent}$$

It is readily seen that the correct allowance for the change in resistance with increasing temperature makes a tremendous difference in the indicated loss of life.

Despite the foregoing calculation showing 430 per cent loss of life when 200 per cent load is applied for 30 minutes, most of us will agree that a transformer will probably carry 200 per cent load for 30 minutes. In fact the transformer subcommittee ("Overloading of Power Transformers," V. M. Montsinger and W. M. Dann, ELECTRICAL ENGINEERING, October 1934, pages 1353–5) permits overloads up to 160 per cent for 30 minutes under emergency conditions following full load in 40 degrees centigrade ambient. However, 200 per cent load for 30 minutes is dangerous and would not leave a transformer in dependable condition.

Table I

	Ultimate Temperature at 150 Per Cent Load, Degrees Centigrade	
	Resistance Change Considered	Resistance Change Neglected
Ambient temperature	40	40
Oil temperature rise over ambient	82	68
Average coil temperature rise over oil	43	34
Hot-spot temperature over average oil	28	22
Hot-spot temperature	193	164

It is unfortunate that Nichols did not publish the temperatures resulting from the various short time overloads that he suggests, since a knowledge of the actual temperatures involved would assist the reader in forming an independent judgment as to the probable severity of such an overload, and as to the probable extent of the injurious effect on the transformer.

The author's graphical solutions for problems of transient thermal behavior of transformers, as shown in figures 4 to 9, are very interesting, and will be useful where the range of temperature is limited, permitting neglect of resistance change.

H. H. Wagner (Pennsylvania Transformer Co., Pittsburgh, Pa.): This paper includes information of practical value on 2 important transformer problems: (1) the calculation of temperature rise, and (2) the effect of temperature on transformer life. Both of these topics have been discussed in detail in previous A.I.E.E. papers, and it appears worth while to include at the end of this discussion a short bibliography of papers directly relating to this subject.

The present paper contributes a useful addition to reference 1 of this discussion by explaining the construction of logarithmic scales for converting the heating curves to straight lines.

Reference 1 provides a detailed explanation of the method of calculating transformer temperature rise under various loading conditions, and includes in addition to the derivation of the heating formula, a discussion of the assumptions, errors, and restrictions in the use of the method; it also points out that for practical purposes the use of only one heating curve formula will serve for both the top oil rise and copper rise above oil temperature, the formula being the one used by Nichols in deriving the logarithmic scale of his figure 9. In any case, however, separate formulas for the time constants of oil and copper should be used as shown in references 1 and 3, and in the present paper. Incidentally, it is noted that an error appears in the formula for the oil time constant on page 1620, which should read

$$\frac{A\,(C + D + E)}{G}$$

I have applied this method several times in the past few years, using only the one heating curve formula, and the agreement between calculated and test results has been quite close.

With reference to the data on the effect of temperature on the life of insulation, it is interesting to compare figure 1 of Nichols with figure 11, page 784 of reference 5. The 2 curves differ quite widely at the lower temperature values, but if the curve of figure 11 is extrapolated to time values below one year, the 2 curves approach each other more closely above 150 degrees centigrade. Figure 1 of Nichols shows a life of $1^1/_3$ years at 105 degrees, and $3^1/_2$ years at 95 degrees; figure 11 of reference 5 shows a life of 7 years at 105 degrees and 16 years at 95 degrees. Based upon experience and upon the recommendations of A.I.E.E. Standards No. 100, it seems to me that Nichols' curve is quite pessimistic in the range around 100 degrees. A.I.E.E. Standards No. 100 recommend a temperature of 95 degrees for continuous operation on a temperature basis, and it therefore seems that $3^1/_2$ years would be an unreasonably short life to expect from such operation.

It is probable that part of the curve at the higher temperatures and lower time values is closer to actual conditions, as a result of the greater facility in making tests in this region because of the decreased time required.

The data in this paper serve to emphasize a danger not often recognized in transformer manufacture—that of using a high temperature in the compound treatment of transformer coils. The method of impregnation by compound which is in quite general use for small transformers (however, not used by the company with which I am associated) involves subjecting the coils to a temperature of approximately 150 to 160 degrees centigrade for a period of 12 or 15 hours. The curve in figure 1 shows, and the statement is made, that when a transformer is operated for 4 hours at 150 degrees, about 4.3 per cent of the life has been consumed. Therefore, on the same basis, a period of 12 hours at 155 to 160 degrees would consume approximately 25 per cent of the life of the insulation. Although the safety factor used in this calculation is probably quite conservative, it is indicated that temperatures of 150 degrees and higher should not be permitted for any length of time. This conclusion is substantiated also by A.I.E.E. Standards No. 13-250*c* which sets a temperature of 160 degrees to be reached for only an instant at the end of a one minute emergency operation.

REFERENCES

1. PREDERMINATION OF SELF-COOLED OIL-IMMERSED TRANSFORMER TEMPERATURES BEFORE CONDITIONS ARE CONSTANT, W. H. Cooney. A.I.E.E. TRANS., v. 44, 1925, p. 611–18.

2. THE THERMAL TIME CONSTANTS OF DYNAMO-ELECTRIC MACHINES, A. E. Kennelly. A.I.E.E. TRANS., v. 44, 1925, p. 137–47.

3. Discussion of reference 2, V. M. Montsinger. A.I.E.E. TRANS., v. 44, 1925, p. 147–9.

4. COOLING OF OIL-IMMERSED TRANSFORMER WINDINGS AFTER SHUT-DOWN, V. M. Montsinger. A.I.E.E. TRANS., v. 36, 1917, p. 711–30.

5. LOADING TRANSFORMERS BY TEMPERATURE, V. M. Montsinger. A.I.E.E. TRANS., v. 49, April 1930, p. 776–90.

6. OPERATING TRANSFORMERS BY TEMPERATURE,

W. M. Dann. A.I.E.E. TRANS., v. 49, April 1930, p. 793–6.

7. SAFE LOADING OF OIL-IMMERSED TRANSFORMERS, E. T. Norris. A.I.E.E. TRANS., v. 48, Oct. 1929, p. 1206–12.

E. A. Church (Edison Electric Illuminating Co. of Boston, Mass.): Several years ago the A.I.E.E. recognized that loads considerably above name-plate rating could be applied to oil insulated transformers when the ambient temperatures were below the standard 40 degrees centigrade. This was incorporated in A.I.E.E. Standards No. 100–5. These standards were all based on continuous loading.

Transformers are almost never operated, however, at a continuous load and it has been felt by operating engineers that considerably greater loads than allowed by Standards No. 100–5 could be allowed during the maximum of daily load cycles on account of the relatively large heat storage capacity of the oil and iron core. Engineers have been hesitant to apply overloads to transformers, however, because of the reluctance of manufacturers to guarantee them for loads exceeding name-plate rating.

In this connection we are interested to note the paper demonstrates that, if a transformer is actually operated at 55 degrees centigrade rise above the standard of 40 degrees and allowing the conventional 10 degrees for hot spots, giving 105 degree insulation temperature, the life of the transformer would be only $1^1/_3$ years. Even if the ambient is 30 degrees, which is the point below which one per cent overload may be applied for each degree lowering of ambient, the life would be only about 4 years, which would be considered entirely too short by the majority in the industry.

It appears that the present standards are entirely too liberal for continuous loading, and perhaps too conservative for cyclic loading. We therefore welcome the paper as a distinct advance in the theory of operation of transformers by temperature.

During recent years economic pressure has forced engineers to make maximum use of existing investment and so considerable need has been felt for a study of the thermal characteristics of transformers in order that the reservoir of heat capacity might be made use of in safely leading transformers to values considerably in excess of the continuous loading rating for a few hours daily. We, accordingly, undertook such a study during the latter part of 1932, some of the results of which will be interesting to note.

Temperature rises in transformers when operated under load cycles frequently met with in a metropolitan area such as on the Boston system have been calculated. These load cycles are illustrated in figure 1 of this discussion. Curve *A* is an average residential load cycle and curve *B* is a combined industrial and residential load cycle giving the highest load factor met with on the system.

Maximum temperatures have been calculated for various ambient temperatures and per cent rated load and the results incorporated in figure 2 of this discussion for the transformers listed in the figure. It should be emphasized that the list includes transformers of all sizes from 1,000 to 25,000 kva and hence the size of a transformer is not a criterion as to the amount of overload which it will carry under cyclic loading. This is apparent from the fact that the temperature rise with time of a transformer is determined by the product of the thermal capacity and thermal resistance, which product is within a narrow range for all sizes of transformers. The principal determining factors in temperature rise of the windings are the ratio of winding rise over oil to oil rise over ambient and the ratio of copper loss at rated load to the iron loss.

Curve *A* of figure 2 gives the load which the transformers listed will carry without exceeding 95 degrees centigrade hot-spot temperature when loaded with the residential load cycle shown by curve *A* of figure 1. Curve *B* gives the load which these transformers will carry without exceeding 95 degrees when loaded with the combined industrial and residential load cycles. Curve *C* shows the continuous load which these transformers will carry without exceeding 95 degrees. This curve is seen to check very closely the one per cent increase in load per degree ambient below 30 degrees as allowed by Standards No. 100–5.

Referring to figure 1 of the paper, if a transformer is operated at 95 degrees centigrade continuously, its life will be about 4 years. The life on the basis of operation on load cycles given by curves *A* and *B* can be estimated by the calculations given in tabular form in table II of this discussion. Oil temperature rise is assumed to be 44 degrees, hot-spot rise 65 degrees at rated continuous load, and ratio of copper loss to iron loss 1.5. The ratio of total loss/rated loss given in item 2 of the table is the total loss over a 24 hour period, divided by the total rated loss × 24.

Table II

	Ambient Temperature, Degrees Centigrade			
	Curve A		Curve B	
	30	0	30	0
Copper loss factor	0.44	0.44	0.61	0.61
Ratio, total loss/rated loss	0.76	1.02	0.85	1.19
Average oil temperature rise, degrees	35.5	44.5	37.5	50.5
Average copper temperature rise, degrees	12.5	21.5	15.5	27.5
Average total temperature rise, degrees	50	66	53	78
Life on basis of average temperature rise, years	12	50	10	15

The actual life will be somewhere between 4 years and the values given in the last item of the table. When we consider that the average summer ambient temperatures are usually lower than 30 degrees centigrade and that the heaviest loading on transformers in metropolitan systems occurs in winter, with ambients near 0 degree, it must be concluded that the transformers listed will have a very long life if loaded on the basis given by the curves of figure 2.

Transformers with different thermal characteristics from the ones listed will, of course, reach their maximum temperatures with different overloads than the ones listed. Calculations have been made and curves similar to those in figure 2 are available for transformers of practically all variations in thermal characteristics. These curves give overloads of the same order of magnitude as given by the figure, showing that transformers may vary widely in thermal characteristics without affecting the overload capacity to a very great extent.

Curves similar to those of figure 2 are being prepared for water and air-blast cooled transformers. Results so far indicate that very little overload capacity on a cyclic loading basis can be expected for these types of cooling. This is what might be expected, since the hot-spot temperature rise above oil temperature increases as the square of the loading and the copper has very little thermal capacity compared to the oil and core. The inherently greater ratio of copper to iron losses in water and air-blast cooled transformers will hence limit the overload capacity obtainable.

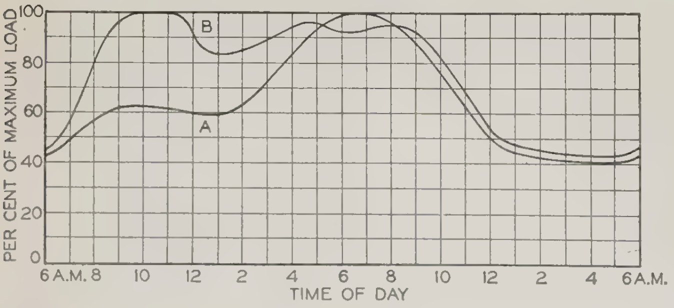


Fig. 1. Load cycles on metropolitan system

A. Residential load cycle

B. Combined industrial and residential load cycle

L. C. Nichols: Referring to the discussion of J. E. Clem, the present A.I.E.E. rules infer a long life of from 20 to 30 years when a transformer is loaded continuously at 100 per cent load, 40 degree centigrade ambient temperature. This condition is unusual but does occasionally occur, resulting in a shorter life than the user expected. Overloading does shorten the life of a transformer but is economically justified.

In answer to the discussion of W. H. Cooney, samples of many kinds of material were placed in oil at 90 degrees centigrade and kept at this temperature continuously for 5 years. Samples were periodically removed and tested. Mechanical tests were made, but the results from these were not conclusive. The best conclusions seemed to come from bending and from observation.

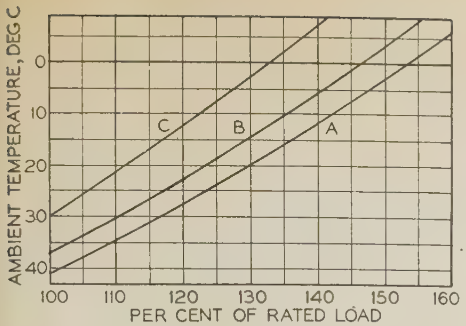


Fig. 2. Maximum load versus ambient temperature without exceeding 65 degrees centigrade hot-spot temperature rise

A. Residential load cycle
B. Combined industrial and residential load cycle
C. Continuous load

Transformer Number	Rating	θ	ϕ	KC
1	1,000	44	1.51	6.71
2	1,500	47	1.36	6.56
3	1,500	43	1.24	6.05
4	3,500	41	1.38	7.38
5	3,500	41	1.42	7.28
6	5,000	44	1.48	7.04
7	25,000	45	2.09	6.10
8	25,000	46	1.61	7.48
Average		44	1.51	6.83

θ = Measured top oil temperature rise
ϕ = Ratio of rated load copper loss to iron loss
KC = Product of thermal resistance and thermal capacity for oil temperature rise above ambient

"Fullerboard," 75 per cent and 100 per cent rag, became so brittle that the least bending would break it, and varnished cloth of various kinds showed the same result. Cotton covered wire showed the cotton had become a dark chocolate brown, was very brittle, and easily rubbed off.

It does not appear in my paper that a transformer has 100 per cent of initial strength until 100 per cent of its life is used up.

Whatever the method of loading a transformer, the mechanical strength decreases with age and deterioration is a function of temperature and time. My conclusion is that insulation will fail mechanically causing electrical failure before the reverse will occur, unless abnormal voltages are applied to the transformer. Under short-circuit conditions or overload the mechanical stresses are more severe than at normal load. The older a transformer is the less its mechanical strength.

When 100 per cent of the life is used up on the basis of my paper, there is great likelihood of failure under severe overloads due to mechanical failure. The transformer would probably last longer if not subjected to the mechanical strain of overloads.

In regard to W. M. Dann's discussion of the 8 degree rule, this has been accepted for a number of years by various authorities as being approximately correct, and I have also found it approximately correct, based on tests and actual operation of transformers in service.

It is granted that instead of the figure of $1^1/_3$ years which I used, someone else might say 3 or 5 years, but the insulation would be in a much worse condition. In my opinion $1^1/_3$ years is more nearly correct.

Replying to Philip Sporn's discussion, I would like to ask him if he ever operated a transformer for several years continuously at 95 degrees centigrade by resistance or 105 degrees centigrade hot-spot temperature. My opinion is that a transformer of any make will not have a long life under this condition. I know of one operator who tried to operate some transformers continuously at 100 per cent load in a 40 degree centrigrade ambient. The transformers burned out after less than 2 years' operation and were replaced with transformers of twice the original size to carry the load.

I am not trying to scare people into buying larger transformers than they need. In a few cases they should use larger transformers. In many more cases a smaller transformer could be used.

In answer to the discussion of Lynn Wetherill, in calculating the loss in life for an overload of 24 hours' duration in a given ambient, it makes practically no difference what the previous load was.

I do not agree with him that the hot-spot correction goes up with the copper loss. If the temperature is calculated from the resistance of the windings, 10 degrees centigrade is added for hot-spot temperature irrespective of the temperature obtained. This is, as I understand it, according to A.I.E.E. rules.

If the hot-spot temperature is calculated as shown by Wetherill, even short time overloads would be dangerous. A transformer of one design may have windings worked as hard at 100 per cent load as another transformer has at 200 per cent load; nevertheless, only 10 degrees is added for hot-spot temperature. Wetherill would add 10 degrees in one and 40 degrees in the other. This difference in calculation of temperature is the difference of a small per cent loss of life and a very large per cent.

Evidently H. V. Putman and I do not differ very much. There is no definite time to say when the life is used up; it is just like an automobile tire. Some people will throw away the tire when the tread shows considerable wear; others would run this tire twice as long or more.

The condition of the insulation in the transformer operated at 175 degrees centigrade for 2 days by Putman indicated in my opinion that the life was quite well used up.

The following typographical errors in the paper should be noted: page 1617, table I, "Overload in Per Cent of Rated Load" should read "Load in Per Cent of Rated Load," and page 1620, the unit of time τ is $A(C + D + E)$ divided by G.

Vibration Analysis—Transmission Line Conductors

Author's closing discussion of a paper published in the November 1934 issue, pages 1478–85, and presented for oral discussion at the general overhead line problems session of the winter convention, New York, N. Y., January 23, 1935. Other discussions of this paper were published in the March 1935 issue, pages 334–5.

W. B. Buchanan (Hydro Electric Power Commission of Ontario, Toronto, Can.): The primary purpose in presenting this paper before the Institute was to invite criticism of a new method of test, radically different from any method hitherto published, which appears to make valuable information available in quite usable form. It is reassuring to know that the scheme was anticipated by Bate (paragraph 7 of his discussion) and to learn that it proved satisfactory so far as he used it. The author would be glad to compare notes with any other engineers who might be working on this or similar schemes.

A second purpose was to introduce the terminology of traveling wave phenomena into this subject in a perfectly rational manner and give public notice that such expressions are likely to be heard more and more as the merits of the method become better known. It might be considered with some justification that the term "vibration" to indicate the standing wave phenomena has little to commend it other than usage. A mental hazard has been introduced by the use of this term and the simplest way in the writer's opinion of minimizing this hazard is to provide an experimental model —some hundreds of feet in length—and observe that the nodes are not the fixed points they appear to be on paper, but depend on other conditions up and down the line, far and near. How otherwise could dampers near the clamps be relied upon to eliminate vibrations at the center of the span?

Two statements in the discussion by Stickley and Sturm seem to be based on a lack of complete understanding of the conditions of the test. Referring to the last sentence of paragraph 5, the cable is not "struck" because the waves introduced would be of quite too steep wave front. The impulse is applied at only one point and the pair of waves is the natural result. It will be found impossible to disturb a conductor near the center of the span without the disturbance proceeding simultaneously in both directions along the conductor.

This pair of waves gives some advantages in testing; twice as many records may be obtained on the same length of film, but a more important feature is that the conductor is subjected to complete reversals of the cycles of stress and hence more consistent values of the attenuation and reflection factors can be obtained.

Paragraph 8 by Stickley and Sturm is difficult to place in relation to anything the author had in mind. The increased length of the cable around the loop has a net over-all effect of slightly reducing the sag of the span as explained under example 5. The longitudinal stress discussed in this case is that associated with longitudinal motion of the conductor at a clamp. This motion is the factor which sets a string of insulators in motion or, if a long string of say 20 units, possibly in oscillation. Records have been obtained which tend to indicate that a 20 unit string of 10 inch insulators is capable of sustaining an oscillation with a 40 per cent damping factor after the application of one impulse and under normal conditions of line construction and loading.

These 2 points seem to be the only items on which there appears to be any disagreement among all correspondents. Any other apparent difference can be explained by a difference in the terminology used. Both contributions to discussion refer to the reaction taking place at clamps or other

Table I—Design Features and Lightning Performance of 220 Kv Lines

1	2	3	4	5	6	7	8	9	10	11	12		13	14	15		16	17	
Line No.	Name of Company	Line Designation	Date First in Service	Length of Line (Miles)	Avg Tower Span (Ft)	No. of Circuits	Circuits per Tower	Tower Design (Fig. No.)	Ground Wires per Tower	Height of Ground Wires Above Cond. at Tower (Ft)	Ground Wire Location (See Figs.) (Feet) A	B	Cond. Height Above Ground at Tower (Ft)	Conductor Spacing (Ft)	Conductor Clearance at Tower In.	At Deg Swing	Clearance Impulse (1x5-μsec pos.) Flashover at Tower, Kv[7]	Suspension Insulators No.	In. Spacing
20	Hydro Electric Power Commission of Ontario, Can.	Chat Falls-Leaside	10/1/28	199.1	1,056	1	1	1	2	13.5	12.6	...	59.7	25.3	72	45	1,460	18	5
21		Paugan-Leaside	1/26/30	227.7	1,074	1	1	1	2	13.5	12.6	...	59.7	25.3	72	45	1,460	18	5
22		Paugan-Leaside	10/15/31	227.9	1,062	1	1	1	2	13.5	12.6	...	59.7	25.3	72	45	1,460	18	5
23		Beauharnois	10/20/32	129.7	1,036	1	1	1	2	13.5	12.6	...	59.7	25.3	72	45	1,460	18	5
				784.4	1,045														

attached masses and their comments are quite valid. A caution, however, should be expressed; masses alone are not energy absorbers and it has, by this series of tests, been shown possible to attach 4 masses at irregular intervals (dissonance producing) adjacent to the clamp in one span and obtain a higher ratio of curvature at the clamp to that in the span than was obtained for the conductor alone. This result would hardly be anticipated from ordinary vibration theory, but it tends to indicate that energy absorbing devices are desirable rather than those having buffer or oscillating characteristics only.

In answer to questions covered by paragraphs 3 to 6 by Bate, the following information is outlined briefly:

A mechanical device using paper and pencil indicated that the arc of curvature due to bending at the clamp was constant from 24 inches down to about 3 inches. A series of readings were then taken by using the carbon pack curvature recorder set with different spacings between the centers of pressure of the clamps from about 2 to 5 inches. The tendency toward high concentration of the stress within a length of about twice the diameter of the conductor was demonstrated quite conclusively though exact figures were difficult to duplicate. Shortening the distance between the clamps reduces the length of arc of the curve being recorded, hence reduces the sensitivity of the recorder. Ratios of curvature at clamp to that in midspan as high as 35 were calculated from measurements and there seems to be no doubt that such ratios do occur in practice when the traveling components predominate as with galloping conductors.

The immediate object of these tests, however, was to determine the effects produced (absorptive or dissipative) of any devices being tried out and for this purpose records are made at the same set-up with and without the device and the answer obtained as a ratio. This avoids the necessity of calibration of units precisely and minimizes the chance of any errors in the results being introduced due to errors in calibration.

Stickley and Sturm present arguments in favor of testing with a multiplicity of waves originating with the wind. The multiplicity of unknown amounts of energy applied at from 50 to 100 different locations in a span is rather too complicated a problem *in toto* from which to derive design data. The advantage of isolating one unit from such a complex series corresponds to the anatomical study of a bee by individual analysis rather than attempting to dissect the entire swarm at once. The social or group influences of course are important and the final criterion is field experience. For purposes of analysis, however, the problem must be broken down somehow, somewhere into independent elements. If the method of test be sound and the methods of analyzing the results valid there need be no fear of the final answer not agreeing with that of any other scientifically correct method of solution.

Before concluding the discussion on this paper the net results accomplished should be reviewed and their significance pointed out as the latter has not yet been fully outlined. Some of the important types of information obtained have been mentioned, which combined with other data prompts the suggestion that natural vibrations should be regarded as a "symptom" rather than as the principal disease itself; a symptom indicative of construction having high reflection and attenuation factors and hence particularly susceptible to damage from all traveling waves.

The development of this problem has some features closely paralleling that of lightning studies. Prior to the use of the cathode ray oscillograph in the field, theoretical discussions were limited practically to discussion of induced charges and very little was said about direct strokes. As the result of knowledge obtained with this oscillograph, present day literature is directed to discussion of direct strokes, their magnitudes and effects, as it was found that induced charges were of approximately the same order of magnitude as switching surges and if insulation were satisfactory to withstand the latter there should be little hazard from the former.

Calculation of the increased stress in a conductor for some of the worst cases of natural vibration on record, supplemented by estimation of the components of stress as measured by these methods, indicates that the transient components associated with standing waves rarely reach 100 per cent of normal tension. Hence the normal factors of safety should be quite sufficient to give indefinite life to the conductor if such were the sole cause of failure. Considerably greater stresses can be set up by traveling waves and doubtless are if some of the moving pictures on this subject can be accepted as valid.

Hence the author respectfully suggests that protection against these waves, which do occur and have such drastic effects, is the vital part of the vibration problem rather than the suppression of standing waves which can be accomplished by comparatively mild palliative treatment. The solution to this problem automatically carries with it the possibility of extending span lengths and tensions to values more nearly approaching the most economical design. There appears to be a state of arrested development in the art at present due to this difficulty.

Test data available and field experience alike tend to indicate that conditions are more aggravated at the higher tensions. Supplementary devices can be added to reduce the attenuation factor to almost any value desired but their mode of action should be examined very critically. The method outlined seems to offer a satisfactory key to the solution of this problem. It would be instructive to have the entire scheme, apparatus, and analysis checked by an independent group of investigators.

Lightning Performance of 220 Kv Lines

Closing discussion of a paper prepared by the lightning and insulator subcommittee of the A.I.E.E. committee on power transmission and distribution published in the November 1934 issue, pages 1443–7, and presented for oral discussion at the general overhead line problems session of the winter convention, New York, N. Y., January 23, 1935.

I. W. Gross (American Gas and Electric Co., New York, N. Y.): In preparing this paper, an attempt was made to obtain operating data on all 220 kv lines in the United States and Canada. At the time this paper was offered for publication, operating data on the 220 kv system of

Table I Continued—Design Features and Lightning Performance of 220 Kv Lines

18	19		20		21				22		23	24		25	26		27	28	
Insulator Impulse (1x5-μsec pos.) Flashover at Tower, Kv[7]	Type of Country		Nature of Soil		Tower Footing Resistance, Ohms				Additional Grounds at Tower		Lightning Severity	Avg Line Outages per 100 Miles of Line per Year		Grading Shields Used	Tower Flashovers per Year Avg		Isoceraunic Factor	Outages per 100 Miles of Line per Year at Isoceraunic Factor of 50	
					Avg		Max.												
	West Half	East Half	West Half	East Half	West	East	West	East	West Half	East Half		West Half	East Half		West Half	East Half		West Half	East Half
1,750	Rolling	Hilly	Clay	Rocky	28	240	170	1,060	None	None	Severe	0.20	2.37	None	0.23	2.08	[16]33	0.3	3.58
1,750	Rolling	Hilly	Clay	Rocky	28	[13]230	170	1.290	None	Limited crowfeet & counterpoise	Severe	0.33	2.48	None	0.36	2.88	[16]33	0.5	3.75
1,750	Rolling	Hilly	Clay	Rocky	28	[14]147	170	570	None	Limited crowfeet & counterpoise	Severe	..	3.07	None	..	2.64	[16]33	...	4.65
1,750	Flat		Clay		[15]16.2		300		Limited crowfeet & counterpoise		Mild	1.43		None	0.91		[17]14	5.12	

13. After the addition of crowfeet or counterpoises to approximately 12 per cent of east half of the middle circuit, Paugan-Leaside, in the section of highest footing resistance, this resistance was reduced from an average of 540 ohms to 86 ohms for the towers checked. 14. After the addition of crowfeet or counterpoises on the south circuit, Paugan-Leaside, on 1/3 of the towers in the eastern half, the average tower resistance was reduced from 147 ohms to 50 ohms. This work was done during the summer of 1934 and hence the beneficial results are not yet apparent. 15. After the addition of crowfeet or counterpoises on occasional towers the ground resistance was reduced to 7.9 ohms. 16. These figures represent the average number of days per year on which storms occurred. 17. Storm days 1934 only. No definite record yet of a crowfoot equipped tower being struck. Except for 4 flashovers, practically all lightning trouble confined to east half of Paugan-Leaside line.

the Hydro Electric Power Commission of Ontario, Can., was not available. Since then the operating record of that company's lines has been received, and we are now submitting the data in table I of this discussion in the same form as presented in table II of the paper.

A few interesting points to note in connection with this company's lines are the use of 2 ground wires, 18 5-inch insulators at suspension assemblies, and, the tower footing resistances being quite high, the special means taken on some towers to lower the resistance by crowfoot counterpoises. Approximately 80 per cent of the lines are located in territory classed as subject to severe lightning. The outages per hundred miles of line per year for their entire system has been given as 1.4 actual, and on an isoceraunic basis of 50, vary from 0.3 to 5.12 with an average of approximately 2.5.

We are glad to be able to give the above record so that a rather complete and up-to-date record is now available on 220 kv line operation under lightning conditions.

Expulsion Protective Gaps on 132 Kv Lines

Authors' closing discussion of a paper published in the January 1935 issue, pages 66–73, and presented for oral discussion at the general overhead line problems session of the winter convention, New York, N. Y., January 23, 1935. Other discussions of this paper were published in the March 1935 issue, pages 329–32, and in the May 1935 issue, pages 557–8.

Philip Sporn and I. W. Gross (both of American Gas and Electric Co., New York, N. Y.): Referring to Ackermann's comments on the type of tube mounting, we gave very careful consideration to this matter before adopting the parallel and V types of mounting, as we felt that the types of mounting which had previously been suggested with the tube fastened to the tower structure and tower arms presented a rather serious and dangerous cluttering up of the tower under operating conditions. For example, regular inspection is made of all towers and assemblies on the lines usually once each year, and for a man to climb up in a maze of tubes and braces and do a satisfactory inspection job would subject him to hazards which we feel did not warrant the tower mounted type of tube.

The parallel and V types of mounting were worked out particularly to enable the removal and installation of the tubes while the line was "hot," and it is believed that this can be satisfactorily done in the field in the same general way as hot line maintenance is done on all our 132 kv lines, although some special hot line tools might have to be developed to take care of this work.

In reference to the matter of measuring the tube erosion with the tube in service, it seems to us that this might be a rather hazardous procedure, although it is possible the scheme could be worked out with special tools for making such measurements.

Opsahl has concluded from the data that about 9 tubes gave indications of operation for each lightning stroke. Accurate figures on this feature are practically impossible to present as there is no way of telling from observing the tubes which have operated whether their operation was the result of one lightning stroke or more than one during a particular lightning storm. The data we have, however, show that several cases occurred where tubes at 4 adjacent towers were observed to have operated during a single storm, and these operations involved as many as 3 tubes on 2 of the towers and one or more tubes on the 2 towers farthest from the center of the disturbance. These tube operations may, of course, have been the result of one lightning stroke, a multiple lightning stroke, or several separate strokes in the same storm.

The suggestion Opsahl has made, that the greater number of tube flashovers on the Glenlyn-Roanoke line might be the result of the lower line insulation and therefore might require a much closer designing of the tube, apparently is not the answer, as the external physical dimensions of tubes and gaps were the same on both lines, and therefore the impulse flashover of the tube assembly when new would be the same.

The point regarding the cost of equipping a line with expulsion tubes mentioned by Hunter is, of course, important; presumably in all cases the economic justification of tube application will be gone into fully before any decisions to proceed are made. It is therefore most important that the first cost of maintenance of these tubes be kept within economic limits.

It is interesting to find that Bellaschi has evaluated the lightning stroke current by methods other than that given in our paper, and has arrived at substantially the same range of currents in the lightning stroke. The authors in their calculation used the effective surge impedance in the tower structure to ground as 100 ohms. On recalculating the tube currents on the basis of actual tower footing resistances, ignoring only the tower surge impedance, we find the tube currents range from 1,000 to 9,500 amperes per tube. This is in the same general range as given by Foust. Like most problems of this kind, the data on the type and location of the origin of the disturbance are uncertain, so that many assumptions must be made, and it is rather remarkable that such close agreement is found although different methods have been used. After all, extreme accuracy is not to be expected in measurements of this kind and the results obtained, where fundamental data are lacking, will be only of the same order of accuracy as the assumptions on which they have been based.

The additional protection against lightning flashover of an unprotected line (2-circuit construction) as brought out by McEachron by the application of tubes on one line seems to confirm our own actual experience in operating a 2-circuit 66-kv line with one circuit overinsulated. It was found that in all cases during the 2 years of operation of this line that all single circuit outages from lightning were confined

to the low insulated line, although there were some cases of 2 circuit outages. In other words, there was never a case where only the overinsulated line had tripped out. This feature of protection may also be of value in case of a tube failure where the flashover of the tube circuit, even though the tube occasionally does not clear the line satisfactorily, may prevent the second circuit tripping out, and in this way avoid a service interruption.

Multiple Lightning Strokes

Author's closing discussion of a paper published in the December 1934 issue, pages 1633–7, and presented for oral discussion at the general overhead line problems session of the winter convention, New York, N. Y., January 23, 1935. Other discussions of this paper were published in the March 1935 issue, pages 332–3, and in the April 1935 issue, pages 444–5.

K. B. McEachron: G. D. Harding has given some details of the tests made in Pittsfield showing the effect of polarity in determining which wire would be struck. The tests seem to indicate that the polarity of the conductor has little to do with determining which one is to be struck, at least under laboratory conditions. I am not at all sure, however, that the method of propagation of the discharge through the air under laboratory conditions is sufficiently like that of natural lightning to be certain that the tests described are conclusive as to the effect of conductor polarity in determining which conductor would be struck. However, it does not seem likely that conductor polarity would have much effect in determining which conductor would be struck, unless operating above the corona potential, and even then its effect cannot be very great.

Since such a high percentage of positive polarity expulsion gap operations was found, and since it is known that most lightning discharges are from negative clouds, there seems to me to be no doubt but that ground wires or towers were struck in a majority of cases. This also agrees with the performance of other lines of similar conductor and ground wire configuration, which have shown material improvement when the tower footing resistances have been improved through the addition of the counterpoise. This would not have been true if line conductors had been struck by lightning in a majority of cases, rather the flashovers of the stricken phases would have remained unchanged, only the involvement of other conductors would have been reduced, except in so far as these are the result of communication of 60 cycle arcs. This effect is not dependent upon the mechanism of propagation of lightning to any appreciable degree, and is one which can be expected to make a real difference in the potential required to flash over tower insulation. Since on a 3 phase system the instantaneous positive potential on the conductors as a whole varies from 50 per cent to 100 per cent of the line to ground potential, and since the usual line insulation has a 60 cycle flashover of about 6 times the normal line to ground potential, a reduction in flashover of as much as 17 per cent might be experienced with a slow negative impulse wave applied. To evaluate this effect properly, the possible wave shapes of natural lightning at the point of inception needs to be known, since the traveling waves on overhead ground wires generally die out. The impulse flashover of a string of insulators may be increased by approximately 17 per cent if the polarity of the lightning and conductor are the same. A flashover of the negative phase presumes that the other 2 phases are positive, or one is zero, and has already flashed over. There is thus a possible variation of 34 per cent in insulation flashover, depending on conductor polarity and assuming flashover occurs at the crest of the power frequency potential. The spread between slow wave insulator flashover on all 3 phases simultaneously is likely to be as much as from 25 per cent to 29 per cent. The percentage effects will be less with steeper waves and higher line insulation. The effect can be easily calculated for any assumed wave and line insulation.

W. B. Buchanan has suggested that counter electromotive force from self-induction might account for the erratic path frequently followed by lightning discharges. This suggestion is interesting, but does not appear to me to be a likely explanation of the reason why lightning does not follow the shortest path.

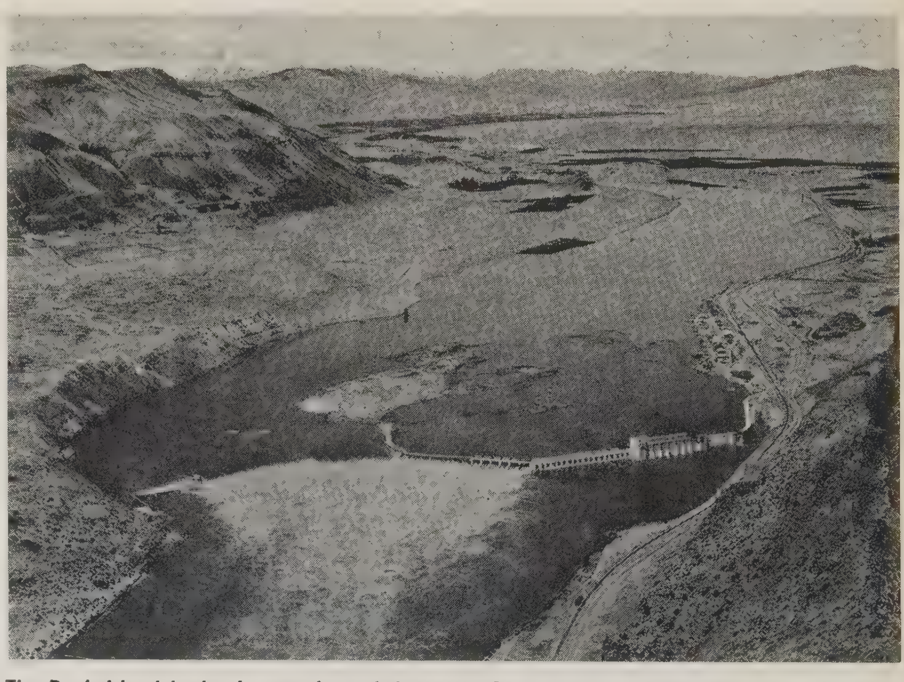
The traveling wave theory is used only to explain the flow of current after a discharge path has once been established. The determination of the path which the discharge will take depends, I believe, upon chance ionization conditions existing in the atmosphere at the time. It would seem that at each point of its progressive travel a new determination is made, not of the shortest path, but of the easiest path.

The research of the next few years should add much to our knowledge of the mechanism of the lightning discharge.

With reference to the time interval between successive strokes, referred to by C. L. Fortescue, it should be noted that times shorter than $^1/_{60}$ of a second could not well be determined by the equipment available. Photographic evidence, reported by Alex Larsen (reference 16 of the paper), indicates times as short as 0.009 second between successive strokes. Additional work may disclose still shorter time intervals.

That reflections, as suggested by C. F Harding, could be the cause of successive expulsion gap operation is most unlikely, as the distances to reflection points are not sufficient to delay reflections so as to cause gap operations in succeeding half cycles. A half cycle is equivalent in time to 8,320 microseconds. This means that if an impulse occurred at the crest of a half cycle, the reflection point would have to be 787 miles away for the impulse to return at the crest of the succeeding half cycle. At a fractional part of such a distance, the original impulse would have attenuated to a negligible value. Therefore, reflections cannot be considered as being important in causing successive expulsion gap operations.

Rock Island Development on the Columbia River



The Rock Island hydroelectric plant of the Puget Sound Power and Light Company, on the Columbia River in central Washington. This plant, constructed in 1932, was the first electric power development on the Columbia River, and the first large low head installation on the Pacific Coast. It is connected with the Puget Sound area by 2 130-mile 110-kv transmission lines. The Rock Island plant, which was described in a paper published in Electrical Engineering for September 1932, pages 654–9, is one of several unusual installations which may be visited during the forthcoming Pacific Coast convention of the Institute in Seattle, August 27–30, 1935

News

Of Institute and Related Activities

Next Month, at Seattle— The Pacific Coast Convention

SEATTLE, Washington, will be host to the 1935 Pacific Coast convention of the Institute which will be held August 27–30, with headquarters in the Olympic Hotel in that city. The convention committee has arranged an excellent schedule of events consisting of 5 technical sessions, 2 Student sessions, entertainment, sports, inspection trips, and specially arranged trips for the visiting women. Also, the convention, which will be held during part of the week preceding Labor Day, will be an important part of the vacation plans of many members. Seattle and the Puget Sound area, bounded by high mountain ranges, are noted for beautiful scenery and attractive vacation possibilities.

A summary of all scheduled events, the technical program and other pertinent information relative to the convention features are given in the accompanying columns. Plan now to attend this interesting convention in the Northwest and keep in touch with the latest professional activities.

Technical Sessions

Five technical sessions in the fields of power transmission, electrical machinery, communication, electrophysics and measurements, and selected subjects embrace a number of timely papers. Many of the papers deal with western engineering developments and they have been prepared by well-known engineers on the Pacific Coast. The engineering features of the Boulder Dam-Los Angeles lines and the 287,000-volt coupling capacitors for the carrier current communication channels will be discussed at the power transmission session. A large part of the electrical machinery session will deal with the leakage reactance and effective armature resistance of synchronous machines. The communication session will have to do with radio telephony in Hawaii and in the Puget Sound area as well as the subject of resonant lines for the frequency control of radio transmitters.

Another session will have papers which will treat the electrophysics of the sphere gap under novel conditions, the direct measurement of surge currents, and the measurement of radio interference crest field strength. Still another session will have papers on several distinctly different subjects, such as the correlation of field data and laboratory data on lightning stroke currents, diesel-electric locomotives, and the production of steam from electric energy.

In addition, 2 Student technical sessions will be held during the convention and the Students from several colleges and universities in Districts 8 and 9 will present a number of interesting papers. These Student papers, as well as all other papers to be presented at the Pacific Coast convention, are listed in the accompanying "Tentative Technical Program."

Rules on Presenting and Discussing Papers

At the technical sessions, papers will be presented in abstract, 10 minutes being allowed for each paper unless otherwise arranged, or the presiding officer meets with the authors preceding the session to arrange the order of presentation and allotment of time for papers and discussion. Authors will be notified officially in each case about one month in advance.

Any member is free to discuss any paper when the meeting is thrown open for general discussion. Usually 5 minutes are allowed to each discusser for the discussion of a single paper or of several papers on the same general subject. When a member signifies his desire to discuss several papers not dealing with the same general subject, he may be permitted a somewhat longer time.

It is preferable that a member who wishes to discuss a paper give his name in advance to the presiding officer of the session at which the paper is to be presented. Each discusser is to step to the front of the room and announce, so that all may hear, his name and professional affiliations. Three typewritten copies of discussion prepared in advance should be left with the presiding officer.

Other discussion to be considered for publication must be submitted, typed double spaced, in triplicate to C. S. Rich, secretary of the technical program committee, A.I.E.E. headquarters, 33 West 39th St., New York, N. Y., on or before Sept. 13, 1935. Discussion received after this date will not be accepted.

Entertainment

Reception and Informal Dance—On Tuesday evening at 9:00 p.m. a reception and informal dance will be held in the Junior Ball Room at the Olympic Hotel.

Salmon Fishing Contest—Wednesday morning contestants will leave headquarters hotel one hour before sunrise as guests of the "Mystic Knights of the Sea" who will furnish tackle. Capital prize will be awarded for the largest salmon. Contestants will return to headquarters hotel at 8:00 a.m.

Banquet—On Thursday evening at 8:00 p.m. a banquet will be held in the Spanish Ball Room of the Olympic Hotel. Following the banquet district paper prizes, golf prizes and fishing contest prizes will be awarded. Tickets will be $1.50 per plate.

Golf—The annual golf tournament for the John B. Fisken trophy will be held on Thursday afternoon at Sand Point Golf and Country Club overlooking Lake Washington. Competition will be medal play on handicap in foursomes. Those expecting to enter the tournament should notify

Summarized Schedule of Events

Monday, August 26

3:00 p.m.—Registration, Olympic Hotel

Tuesday, August 27

9:00 a.m.—Registration, Olympic Hotel
10:00 a.m.—Opening of convention
10:15 a.m.—Technical session on power transmission
2:00 p.m.—Technical session on electrical machinery
9:00 p.m.—Reception and informal dance

Wednesday, August 28

One hour before sunrise, salmon fishing contest
9:00 a.m.—Technical session on communication
2:00 p.m.—Student technical session
2:00 p.m.—Entertainment for women—boat trip from Lake Washington through Government locks into Puget Sound
8:00 p.m.—Conference on Student activities by officers and counselor delegates of Districts 8 and 9

Thursday, August 29

9:00 a.m.—Technical session on electrophysics and measurements
1:00 p.m.—Golf tournament, Sand Point Golf Club
2:00 p.m.—Inspection trips for nongolfers
2:00 p.m.—Bridge luncheon for women, Sand Point Golf Club
8:00 p.m.—Banquet—Presentation of District paper prizes
Presentation of golf prizes
Presentation of fishing prizes

Friday, August 30

9:00 a.m.—Technical session on selected subjects
2:00 p.m.—Student technical session
2:00 p.m.—Automobile tour of Seattle for women

Saturday, August 31

Inspection trips

G. E. Quinan, Puget Sound Power and Light Company, Seattle, and advise him of their club handicap. The green fees will be $1.

Women's Entertainment

Boat Trip—A very pleasant boat trip is planned for the women on Wednesday afternoon. The boat will leave Leschi dock, cruising along the shore of Lake Washington and through the government locks into Puget Sound. After a trip around the harbor the boat will land at Coleman dock.

Bridge Luncheon—The women will be entertained with a bridge luncheon at the Sand Point Golf and Country Club on Thursday afternoon.

Automobile Trip—Friday afternoon the women will be taken for an automobile ride around Seattle's scenic boulevards. The trip will include the government locks, the University of Washington, city parks and the boulevard along Lake Washington.

Inspection Trips

The committee in charge of trips will conduct parties on local trips in the city. The committee will furnish full information and assist in arranging trips to points of scenic or engineering interest outside the city during and after the convention. Complete information on any of the longer trips may be secured from Wellington Rupp, Puget Sound Power and Light Company, Seattle.

Short City Trips

University of Washington
8000 kw electric boilers—Puget Sound Power and Light Company
Automatic Telephone Exchange—The Pacific Telephone and Telegraph Company
Government locks connecting Puget Sound and Lake Washington
Electrification Facilities of the Chicago Milwaukee and St. Paul Railway

Trips Outside the City

Mount Rainier national park
Bremerton—U. S. Navy Yard
Snoqualmie Falls power plant of Puget Sound Power and Light Company
Cedar Falls power plant of City of Seattle Lighting Department
Victoria, British Columbia

Suggested Trips at Close of Convention

Skagit River development of the City of Seattle lighting department
Baker River development of the Puget Sound Power and Light Company
Lake Cushman development of the City of Tacoma lighting department
Rock Island development of the Puget Sound Power and Light Company on the Columbia River
Grand Coulee project on the Columbia River near Spokane
Bonneville project on the Columbia River near Portland

Tentative Technical Program

All papers except those in the student sessions are scheduled for publication in Electrical Engineering prior to the convention. For the papers which already have been published reference to the issue and page is given after each title in the list which follows. The remaining papers are scheduled for publication in the August issue.

Tuesday, August 27

10:15 a.m.—Power Transmission

Engineering Features of the Boulder Dam-Los Angeles Lines, E. F. Scattergood, Bureau of Power and Light, City of Los Angeles
May issue, p. 494–512

*287,000-Volt Coupling Capacitors for Boulder Dam, E. D. Eby, General Electric Co.

Informal discussion of the Grand Coulee and Bonneville power projects on the Columbia River

2:00 p.m.—Electrical Machinery

Test Values of Armature Leakage Reactance, T. A. Rogers, University of California
July issue, p. 700–5

Tests on Armature Resistance on Synchronous Machines, B. L. Robertson, University of California July issue, p. 705–9

Steady State Solution of Saturated Circuits, Sterling Beckwith, Allis-Chalmers, Milwaukee July issue, p. 728–34

Time-Temperature Tests to Determine Machine Losses, M. D. Ross, Westinghouse Electric and Mfg. Co. May issue, p. 512–5

Wednesday, August 28

9:00 a.m.—Communication

*Resonant Lines for Frequency Control of Radio Transmitters, C. W. Hansell, R. C. A. Communications, Inc.

*The Hawaiian Radio Telephone System, W. I. Harrington, Mutual Telephone Company of Hawaii, and C. W. Hansell, R. C. A. Communications, Inc.

*Harbor Craft Ship-to-Shore Radio Service in the Puget Sound Area, E. B. Hansen, Pacific Tel. and Tel. Co.

2:00 p.m.—Student Technical Session

Torque in a Bipolar Induction Type Instrument, Ralph Morton, University of British Columbia

Taxation of Private and Municipal Power Systems in Washington and Idaho, Clement Strefus, University of Idaho

Vacuum Tube Voltmeter for Measurement of High Voltages, E. C. Ryan, University of California

High-Capacity Low-Voltage Bus-Bar Design, Preston L. Adkins, Oregon State College

Precise Speed Control of a D-C Motor, Edward Simmons, California Institute of Technology

A Laboratory Beat-Note Oscillator, Stephen S. Stevens, University of Southern California

Thursday, August 29

9:00 a.m.—Electrophysics and Measurements

The Sparkless Sphere Gap Voltmeter, R. W. Sorensen, J. E. Hobson, and Simon Ramo, California Institute of Technology
June issue, p. 651–6

*Spark Lag of the Sphere Gap, Abe Tilles, University of California

Direct Measurement of Surge Currents, C. M. Foust and J. T. Henderson, General Electric Co. April issue, p. 373–8

Measurement of Radio Interference Crest Field Strength, F. O. McMillan and H. G. Barnett, Oregon State College

Friday, August 30

9:00 a.m.—Selected Subjects

Lightning Stroke Currents—in Field and Laboratory, P. L. Bellaschi, Westinghouse Electric and Mfg. Co.

Diesel-Electric Motive Power for Railroads, A. H. Candee, Westinghouse Electric and Mfg. Co.

Production of Steam From Electric Energy C. R. Reid, Shawinigan Water and Power Co.
July issue, p. 712–9

2:00 p.m.—Student Technical Session

Stereophonic Phonograph Recording, John T. Mullin, University of Santa Clara

Polarity Characteristics of Sphere Gap Spark-Overs, James Biele and Don Pugsley, University of Utah

Experimental Study of Resonant Lines as Radio Circuit Elements, L. M. Hollingworth, Stanford University

Five Meter Transceivers, Harold Backen and Austin Nelson, Montana State College

Ultra Short-Wave Communication, Gordon Clothier and Gilbert C. Larson, University of Washington

* These papers are under consideration for presentation at the Pacific Coast convention, but up to date of going to press have not been officially placed upon the program.

Hotel Accommodations and Registration

The Olympic Hotel in metropolitan Seattle has been designated as the convention headquarters hotel. On Monday, August 26, a general information and registration desk will be opened in the lobby of the hotel where delegates and guests will register and receive badges. Information relative to the various convention activities will also be available to aid the delegates in programing their convention schedule.

The Olympic Hotel rates for delegates are:

	Rate per Room
Single room with bath	$3
Double room with bath	$4
Double room (twin beds) with bath	$5 and $6
Students (several per room)	$1

A number of other hotels and apartment hotels within walking distance are available at approximately the same rates as quoted above. It would be appreciated if members could make their reservations in advance. In so doing please address reservations to E. B. Hansen, The Pacific Telephone and Telegraph Company, 820 Fairview No., Seattle, Washington.

A small fee of $1 for members and $0.50 for Students will be charged to defray a part of the convention expense. A registration fee of $2 will be charged all nonmembers, except Enrolled Students and the immediate families of members. Tickets for the banquet and golf fees may be purchased separately by members interested in these events.

Committees

In the following list are given the members of the 1935 Pacific Coast convention committee, which includes the 7 subcommittee chairmen, as indicated.

E. A. Loew, *chairman*
L. B. Robinson, *vice chairman*
G. H. Walker, *secretary*
F. J. Bartholomew
A. M. Bohnert
Walter Brenton
Fred Garrison
R. H. Hull
F. C. Lindvall
F. O. McMillan
E. O. Osburn
H. T. Plumb
C. E. Rogers
R. W. Sorensen
J. A. Thaler
G. L. Hoard, meetings and papers
E. B. Hansen, hotel and registrations
L. B. Robinson, finance
R. U. Muffley, entertainment
Wellington Rupp, transportation
G. E. Quinan, golf
R. E. Kistler, publicity

President Johnson's Address at the A.I.E.E. Summer Convention at Ithaca

THE Institute's fifty-first annual summer convention, held this year on the campus of Cornell University, Ithaca, N. Y., June 24–28, opened auspiciously. The first day's registration totaled 550, even though none of the technical sessions started until the second day. At the annual business meeting held as part of the opening session on Monday, 330 persons were present, and the several preliminary conferences were well attended. A full report of this convention is scheduled for the August issue.

Received in time for inclusion in the present issue, however, was the president's address delivered at the opening session. This address, read for President J. Allen Johnson by Vice President R. B. Bonney, who presided for him at the opening session, was as follows:

It is with the deepest regret that your president finds it impossible, due to illness, to attend this convention in which, for obvious reasons, he has a very special interest. However, he is glad to be able to send you this brief message.

During the past several years the Institute has suffered a considerable loss in membership. To the extent that this loss has been due to the industrial depression it is neither surprising nor necessarily serious, but I do not think that we should thoughtlessly assume that all of these losses have been due to the depression.

Electrical science, art, and industry, although their main branches of light, heat, power, communication, etc., have long been established, are still undergoing processes of vigorous growth. These processes, in common with all growth, include constant division and differentiation resulting in greater and greater specialization.

Now if the Institute is to maintain its place in this picture as a forum for discussion and a repository of information, it seems to me quite obvious that it must keep pace, in its various activities, with the growth of the science, art, and industry. This means, of course, greater and greater differentiation in its technical committees and subcommittees and also more and more opportunities for discussion among more and more though perhaps smaller groups. In other words, if the Institute is to keep in step with the art it must plan to conduct its technical activities on a finer and finer scale as time goes on.

You will note from your programs that at this summer convention there have been scheduled no less than 14 "technical conferences" or round table discussions, in addition to the 10 technical sessions. It seems to me that a convention held, as this one is, at a great university where almost unlimited meeting rooms are available, lends itself particularly to this type of activity. When you combine with this condition the extremely low cost of living accommodations it seems to me you have a very happy combination of circumstances which ought to result in a large attendance, especially on the part of our younger members, with a resultant very desirable broadening of the usefulness of our summer conventions.

I think the Institute owes a debt of gratitude to Cornell University for its generosity in placing its facilities at our disposal for this pioneering venture in a new type of Institute summer convention. It is my earnest hope that in future years others of our great technical schools having suitable accommodations may likewise open their doors to us, and that the success of this convention may be such that our future boards of directors will be moved to hold many future summer conventions under similar conditions. Should this practice, indeed, develop into a tradition, I feel sure that engineering executives of large enterprises, under whose charge so many of our younger members work, could easily be persuaded to require these young men, as a matter of course, to attend the annual midsummer conventions of the A.I.E.E. in ever-increasing numbers to the obvious benefit of all concerned.

Additional Awards for 1934 Institute Papers

In addition to the national and District prizes for papers presented before the Institute during the calendar year 1934, as announced in ELECTRICAL ENGINEERING for June 1935, page 677, announcement now has been made of the award of prizes for Districts No. 1 and No. 2. These awards are:

DISTRICT NO. 1

Prize for best paper awarded to E. H. Bancker (A'23, M'30) and E. M. Hunter (A'28) for their paper "Distance Relay Action During Oscillations," published in ELECTRICAL ENGINEERING for July 1934, pages 1073–80 and discussed at the North Eastern District meeting, Worcester, Mass., May 16–18, 1934.

Prize for initial paper awarded to E. W. Kimbark (A'27) for his paper "Experimental Analysis of Double Unbalances," presented at the North Eastern District Meeting, Worcester, Mass., May 16–18, 1934.

DISTRICT NO. 2

Prize for initial paper awarded to C. K. Gieringer (A'35) for his paper "A New Alternating Current Null Indicator," presented at meeting of the Cincinnati Section, May 14, 1934.

Branch Activities at University of Arizona

The Institute's University of Arizona Branch at Tucson completed its most successful year, with considerable activity evidenced on the university campus. Meetings were held, with few exceptions, every week, with a topic discussed by a student or professor, followed by a general talk in which all took part. These talks covered a variety of subjects, ranging from illumination installations, through radio television, to a description of a trip through a manufacturing plant.

Besides the regular weekly meeting, several field trips were arranged. Among these were the following: Southern Pacific Railroad signal and repair shops and inspection of Brill gasoline-electric rail car; Department of Commerce radio communication and radio beacon installation at U.S. Army airport; Mountain States Telephone Company and American Telephone and Telegraph Company equipment; refrigerating plant of Pacific Fruit Express; inspection of projectors and sound equipment under actual operating conditions at Fox West-Coast Theatre; and a power plant at Colossal Cave, limestone caverns near Tucson.

It is planned to increase the number of field trips and expand the interests of the Branch during the coming year.

Additional Plans for Great Lakes District Meeting

Plans are progressing rapidly for the meeting of the Great Lakes District of the A.I.E.E. which will be held at Purdue University, West Lafayette, Ind., October 24–25, 1935. Headquarters will be in the Electrical Engineering Building.

The technical program now being arranged by the program committee with C. Francis Harding, chairman, will be of a high technical order. In addition to the subjects announced for this meeting in ELECTRICAL ENGINEERING for June, page 669, interesting papers in the fields of electrophysics and electrical machinery have been prepared. Some of these papers deal with the characteristics of luminous tube circuits, Fourier series analysis of rectifier circuits, and a multiharmonic electrostatic audiofrequency generator. Others have to do with split phase starting of 3 phase induction motors, simultaneous loads at full and half-voltage from a transformer bank with delta connected secondary, and the magnetic field in and near the copper conductors of electrical machinery.

In conjunction with the Great Lakes District meeting at Purdue a Student convention also will be held.

Future AIEE Meetings

Pacific Coast Convention,
Seattle, Wash., Aug. 27–30, 1935

Great Lakes District Meeting,
West Lafayette, Ind., Oct. 24–25, 1935

Winter Convention,
New York, N. Y., Jan. 28–31, 1936

North Eastern District Meeting,
New Haven, Conn., May 1936

Summer Convention,
Los Angeles, Calif., June 22–26, 1936

Middle Eastern District Meeting,
Akron, Ohio (date to be determined)

Leipzig Fair. The Leipzig (Germany) Trade Fair will be held this fall, August 25–29, 1935. The historic fair has been held for 700 years.

The E.C.P.D. Program to Gain Recognition for the Engineering Profession

WHO is an engineer, and by what right does he use that title or undertake to practice engineering? At present there is no single criterion by which an engineer's qualifications can be measured, either by his fellows or by the public that uses his services. The legal status of an engineer is determined in some states by a process of examination, registration, and licensing. His educational status may be indicated by a college degree, and his technical qualifications by his grade of membership in a national society of high repute. Not all engineers are licensed. Neither do they all possess college degrees nor hold membership in a technical society. From the point of view of professional solidarity the situation is chaotic.

As part of its plan to enhance the professional status of the engineer, the Engineers' Council for Professional Development has undertaken to define minimum qualifications of education and experience, the fulfillment of which will entitle an engineer to be recognized as such among his fellows and in his relations with the public. E.C.P.D. is a conference of engineering bodies directly representing the professional, educational, technical and legislative phases of an engineer's life. The participating bodies are the American Society of Civil Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, American Institute of Mining and Metallurgical Engineers, American Institute of Chemical Engineers, Society for the Promotion of Engineering Education, and the National Council of State Boards of Engineering Examiners.

Through its committee on professional recognition, on which the participating bodies are represented, E.C.P.D. has proposed a "minimum definition of an engineer," and a "program of certification into the profession." The definition of an engineer, sets up minimum qualifications of technical education and practical experience, supported by examinations designed to indicate the individual's ability to be placed in responsible charge of engineering work and to render him a valuable member of society. These proposals are now before the governing boards of the constituent bodies of E.C.P.D. When approved they will provide the criterion and the mechanism for professional recognition of engineers.

The program of certification into the profession was drafted by Dr. D. B. Steinman who represents the National Council of State Boards of Engineering Examiners on E.C.P.D. He is also a member of the committee on professional recognition of which Conrad N. Lauer, president of the Philadelphia Gas Works, is chairman. The certification program recognizes the fact that the equivalent of a "grandfather clause" must be applied to permit automatic certification of those who are now recognized and accepted as engineers by legal authorities and by the profession. It also contemplates a reasonable transition period for the progressive adjustment of requirements and tightening of standards until the full program of E.C.P.D. for certification can be put into effect. Thus licensed engineers and certain members of technical societies will be automatically eligible to receive certificates according to a chronological plan up to January 1, 1938, at which time a prescribed procedure leading to certification will be put into effect. When that goal is reached it is hoped and expected that certification of an engineer by E.C.P.D. will set a minimum standard of professional training and experience by which he will be accepted and recognized among his fellows and in his relation with the public.

With the foregoing considerations in mind, the following program of certification is recommended for adoption by the constituent societies, in order to provide smooth, practical transition from present operating procedure to the procedure projected by E.C.P.D. This program was formally approved by the board of directors of the A.I.E.E on June 26, 1935.

Program

1. It is recommended that E.C.P.D. be authorized to publish an annual roster of all engineers certified by E.C.P.D. No filing fees should be charged for listing in the roster, but a charge should be made for copies of this directory to defray the cost of assembling and printing. This roster should preferably list the engineers geographically, by states and territories, also in a comprehensive alphabetic index. The main listings should give the names, educational degrees, professional designations and addresses of the certified engineers. The roster will list between 40,000 and 100,000 engineers.

2. It is recommended that E.C.P.D. be authorized to offer to certified engineers a certificate suitable for framing and display. For any such certificates ordered, a fee should be charged sufficient to defray the cost.

3. It is recommended that E.C.P.D. be authorized to notify all engineers when they are certified, requesting filling out of card with information desired for the roster and enclosing order blanks for rosters and certificates.

4. Until January 1, 1936, the following engineers should be granted certification by E.C.P.D.:

(*a*). All those who are registered or licensed as engineers by the legally constituted authorities of any state or territory of the United States.

(*b*). All those who have been granted certification by the National Bureau of Engineering Registration.

(*c*). All those who are enrolled in the following grades of membership in the following national engineering societies:

A.S.C.E.—Associate Member, Member, Honorary Member
A.S.M.E.—Associate Member, Member, Honorary Member
A.I.E.E.—Member, Fellow, Honorary Member
A.I.M.E.—Member, Honorary Member
A.I.Ch.E.—Active Member

(*d*). All those who have once been qualified under *a*, *b*, *c*, may be granted certificates upon application.

(*e*). Nothing in the previous paragraphs shall be construed as qualifying for certification any person whose license or membership has ever been revoked for unprofessional conduct.

5. Until January 1, 1937, the following engineers should be granted certification by E.C.P.D. (in addition to those previously certified by E.C.P.D.):

(*a*). All those who are registered or licensed as Engineers in any state or territory having statutory requirements at least the equal of those specified in the "model registration law."

(*b*). All those who are certified by the National Bureau of Engineering Registration as having met the requirements specified in the "model registration law."

(*c*). All those who are admitted to the following grades of membership in the following national engineering societies:

A.S.C.E.—Associate Member, Member, Honorary Member A.S.M.E.—Associate Member, Member, Honorary Member A.I.E.E.—Member, Fellow, Honorary Member A.I.M.E.—Member, Honorary Member A.I.Ch.E.—Active Member	or equivalent grade

6. After January 1, 1937, certification by E.C.P.D. should be only on individual application. By that date E.C.P.D. should have set up a bureau of certification with a secretary and staff to receive and review applications, to check references and credentials, and to conduct examinations. (It may be desirable to make this a joint agency with the National Bureau of Engineering Registration which is already functioning in such capacity.) A fee should be charged for each application and examination, and a smaller fee for each reconsideration or re-examination requested by the applicant. These fees should be no larger than necessary to make the E.C.P.D. bureau self-supporting. Each applicant must submit, on suitable forms prepared and furnished by E.C.P.D., full information on education and experience, with names of references for verification.

Membership—

Mr. Institute Member:

Even though it is summer time the Section membership committees are active in contacting those whose names you are sending in.

For May 1935, the number of membership applications received was 53 as compared with 42 applications received during May, 1934—an increase of 26 per cent.

Chairman National Membership Committee

7. Until January 1, 1938, the E.C.P.D. bureau of certification may waive either written or oral examination, or both, in the case of applicants of obvious fitness as evidence by their records of performance.

8. After January 1, 1938, certification by E.C.P.D. should be strictly on the full requirements of the E.C.P.D. standard as embodied in the "minimum definition of an engineer" with the provision that no new applicants shall be excused from examination. The submission of a satisfactory original thesis or published professional paper covering an engineering project executed by the applicant and preferably including an analysis of economic aspects of the project may be accepted as the equivalent of the required written technical examination. The submission of a certified list of courses taken and books studied on cultural, civic and economic subjects, together with a satisfactory original essay or published paper on a cultural, civic or economic subject may be accepted as the equivalent of the required written examination on economic and cultural subjects. The oral examination may be conducted by a local committee of 2 or more engineers or engineering educators, designated by E.C.P.D., and should include a test-review of the applicant's recent reading in cultural and economic subjects, of his continued post-college study of technical subjects, and of his professional growth through observation and experience in his daily work.

9. Arrangements should be made, so far as practicable, to secure agreements to recognize E.C.P.D. certification as *prima facie* evidence of qualification for registration or licensing by state boards and for admission to the corporate membership grade (preferably designated "member") in the national engineering societies. Such agreements to recognize E.C.P.D. certification should be mentioned in the announcements and printed matter of E.C.P.D.

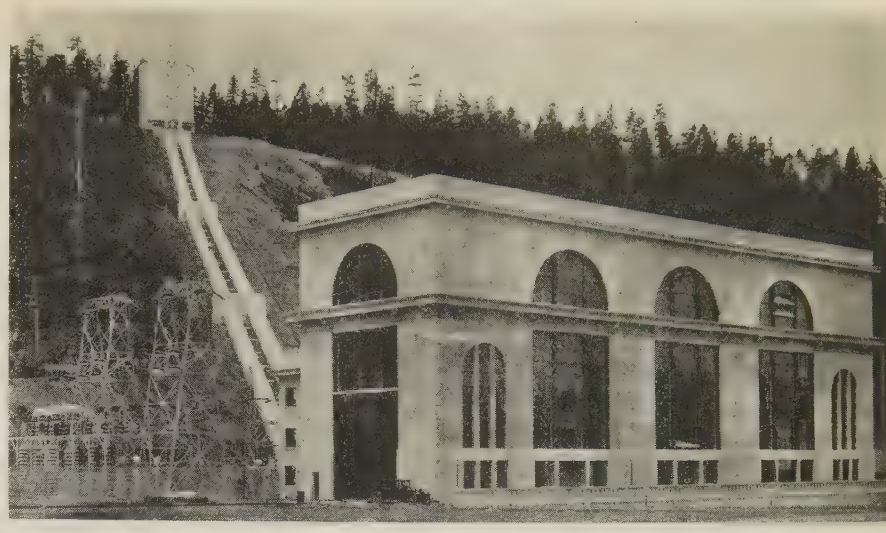
10. The foregoing time-schedule for the progressive development of the E.C.P.D. program of certification is planned to allow necessary time for the development to functioning of the other activities of E.C.P.D., including specifically the accrediting of engineering schools and the post-college training of recent graduates. So far as practicable, the development of these other activities of E.C.P.D. should be timed so as not to delay the putting into operation of the program of certification as herein scheduled.

The goal should be complete functioning of the E.C.P.D. program in its interrelated functions by January 1, 1938.

A.S.T.M. Awards Medal. The Charles B. Dudley medal for 1935, awarded annually by the American Society for Testing Materials, to the author or authors of the paper presented at the preceding annual meeting which is of outstanding merit and constitutes an original contribution to research in engineering materials, has been awarded to C. A. Hogentogler, senior highway engineer, and E. A. Willis, assistant highway engineer, U.S. Bureau of Public Roads. The winning paper presented in 1934 by these 2 authors was entitled "Subgrade Soil Testing Methods." The medal was formally awarded to the authors at the annual A.S.T.M. dinner June 26, 1935, during the thirty-eighth annual meeting of the society in Detroit, Mich.

Transit Association to Meet. The 54th annual convention of the American Transit Association will take place at the Ambassador Hotel, Atlantic City, N. J., September 23–25, 1935. Meeting with the American Transit Association will be its 4 affiliated associations, accountants' association, claims association, engineering association, operating association, and the newly formed bus division. The usual manufacturers' exhibition will be dispensed with this year. Committee meetings in connection with the convention will be scheduled for September 21 and 22.

May Be Visited After the Pacific Coast Convention



CUSHMAN power house number 2 of the department of public utilities of the City of Tacoma, Wash. This plant, 1 of 2 supplied with water from Lake Cushman, is in the Olympic Mountains near Seattle. It is one of the many hydroelectric plants which may be inspected following the A.I.E.E. Pacific Coast convention in Seattle, August 27–30

A Marriage Between 2 Institute Members

An event, unusual in the history of affairs of Institute members, was the marriage in Los Angeles, Calif., on June 7, 1935, of Mabel MacFerran (A'28) and E. W. Rockwell (A'21, M'35) both being members of the Institute. In addition, they are both successful electrical engineers, active in their profession.

The former Mabel MacFerran, now Mrs. Rockwell, studied at Bryn Mawr College, subsequently obtaining the degree of bachelor of science in mathematics from Massachusetts Institute of Technology, and that of engineer in electrical engineering at Stanford University. She spent one summer as assistant in the standardizing laboratory of Leeds and Northrup Company, Philadelphia, Pa., and in 1926 joined the Southern California Edison Company Limited as apprentice testman. She then became technical assistant to the operating engineer of the company, and in 1932 was made an assistant electrical engineer of the Metropolitan Water District of Southern California, at Los Angeles, which position she has since held. She has been active on work dealing with high voltage power transmission and has presented several papers and discussions before the Institute.

Mr. Rockwell received the degree of bachelor of science in electrical engineering from the University of Southern California, and from 1920 to 1931 was in the engineering department of the Southern California Edison Company Limited in charge of electrical substation design. Since 1931 he has been an electrical engineer with the Metropolitan Water District of Southern California, at Los Angeles, engaged on the design and layout of the construction power system for the Colorado River Aqueduct, and the design of the transmission and power system for delivery of power from Boulder Dam to the Colorado River Aqueduct.

Three other couples, both members of which are members of the Institute are:

Ellis Blade (A'35) heat treatment engineer, John Chatillon and Sons, New York, N. Y.; and Mrs. Mary Francis Blade (A'35) interviewer, New York State Employment Service, Brooklyn, N. Y. Mrs. Blade is a daughter of H. T. Plumb (A'03, M'21, and past vice president) engineer for the General Electric Company, Salt Lake City, Utah. Both Mr. and Mrs. Blade were Enrolled Students previous to becoming Associate members.

Roland R. Miner (A'30) electrical engineer, Kansas Gas and Electric Company, Wichita; and Mrs. Roland R. Miner (A'29) Wichita, Kansas.

Fred P. McBerty (A'12) general manager, Federal Machine and Welder Company, Warren, Ohio; and Mrs. Zella A. McBerty (A'24) secretary and treasurer, Federal Machine and Welder Company, Warren, Ohio.

A list of the 10 women who at the time of the publication of the 50th anniversary (May 1934) issue of ELECTRICAL ENGINEERING were members of the Institute was given on page 835 of that issue. Two of these have since resigned, and with the recent addition of Mrs. Blade, 9 women are members at the present date.

Institute Treasurer Honored. Walter I. Slichter (A'00, M'03, F'12, and treasurer) was recently honored by a testimonial dinner given by the members of the staff of the department of electrical engineering of Columbia University, New York, N. Y., to celebrate the completion of 25 years as head of the department. Both present and former members of the staff and other officers of the university and their wives took part in the event, which was also marked by the presentation of a handsome desk set. Professor Slichter has served the Institute as its national treasurer continuously since 1930.

The 8 Joint Functional Organizations of the National Engineering Societies

To provide an effective opportunity for an increase in knowledge, understanding, and general interest in the various phases of the work of the several joint organizations created by the national societies to serve the engineering profession, a special meeting was held in the Engineers' Club in New York, N. Y., on Monday evening, May 20, 1935. Those present at this dinner and general discussion meeting included a large proportion of the officers and directors of the national societies of civil, mining and metallurgical, mechanical, and electrical engineers, together with members of the governing bodies of their several jointly sponsored functional organizations, and a few special guests. A total of 89 persons were in attendance. Of these, 27 were members of the A.I.E.E., their names being given in the news report of the meeting published in Electrical Engineering for June 1935, pages 676–7.

Carefully prepared concise statements covering the scope and significance of the work of each of the 8 jointly sponsored organizations were delivered at the meeting. In order that the membership of the Institute may be acquainted with the work of these organizations, essentially full text of these statements is presented herewith. The first statement, that describing United Engineering Trustees, Inc., is in the form of the president's report for work accomplished during the year 1934. The other 7 are general descriptions of the respective organizations.

United Engineering Trustees, Inc.

By Harold V. Coes, President

President's Report, 1934

The United Engineering Trustees, Inc., entered 1934 with its budget stripped of all operating expenditures which could be postponed. Some active problems which faced the trustees included: (*a*) meeting occupancy competition with other buildings, necessitating study of the condition of the Engineering Societies Building, certain replacements and repairs being inevitable; (*b*) as trustees of funds, the income of which provides for active research, the responsibility was great in obtaining income while maintaining the security of the principal; and (*c*) in an effort to help its founder societies and associates, the rebates in occupancy assessments were continued, and budgets were reduced below minimum of necessary operating costs, but expenses have been kept within these budgets. Fortunately, the business recession seemed to turn upward during the year and the use of the meeting halls and facilities was somewhat better than had been anticipated. Some income producing office space was released, but much of this was filled promptly, and the return from investments were fully up to expectation.

Properties for which the corporation is responsible (real estate at cost, funds at book value and library as appraised) total nearly $4,000,000. The aggregate book value of investments on December 31, 1934 was $1,338,852.98 and the market value was $1,236,677.25. It is noteworthy that the market has advanced during 1934, on practically all securities held by the Corporation.

One very important action of the trustees was the revision of by-laws, for the purpose of meeting changing conditions which necessitated changes in practices, procedure, and personnel. After a very earnest study by the Committee, and thoughtful discussion by the trustees, covering several months, the final draft was referred to the founder societies, and has been approved.

Owing to the study several years ago, of ways and means to rebuild, maintenance on the present Engineering Societies Building has been deferred until some parts reached the stage where criticism demanded that some action be taken. Accordingly a building improvement committee examined conditions and complaints, and authorization was granted by the trustees for redecorating the fifth floor assembly halls, the main floor lobby, reupholstering the auditorium seats and lobby furniture, providing new chairs for the assembly halls, new and adequate illumination in office space and assembly halls, repairing leaky windows and conserving heat and comfort. General commendation indicates appreciation on the part of users of the hall and offices for the improvements.

The board of trustees has recognized that its function is to act for the founder societies in certain important activities which have been entrusted to it, and to incur no new obligations unless so requested by the founder societies. During the past year the board has endeavored to clarify procedures, by-laws and methods, in order to transact the business before it in an expeditious and efficient manner, and the business could be greatly expedited if it were not due to the difficulties from trustee absences. In many cases none of the trustees of a founder society is present, or in other cases not enough of them are present to put through the required votes. The members of the board have ever kept before them that they represent the founder societies. In this group, under its charter and organization, the founder societies have a vehicle which is physically and legally competent to expand its activities for the societies in their joint undertakings, thus eliminating the necessity for new machinery or additional organizations for joint activities in many cases that may arise. The trustees hope that through the founder societies' individual trustees they will call the attention of the board to such matters they wish the board to undertake for them jointly and also to such matters as will, in the judgment of any society, improve the service.

The annual audit shows the affairs entrusted to the corporation by the founder societies, to be in good condition. Several highly important things have been accomplished in 1934 which would tend to unify further the co-operation among the great professional societies and the understanding and sympathy toward their mutual problems. The trustees appreciate the cordial assistance given by the societies, their officers and staffs in making possible the accomplishments of 1934.

The Engineering Societies Library

By Walter I. Slichter, Chairman

Our Engineering Societies Library was established in 1907, when 3 of the founder societies combined their separate libraries into one collection in common quarters.

In 1913 these were formally organized into the Engineering Societies Library, and in 1916 the American Society of Civil Engineers joined us by adding their very considerable collection to the joint venture.

This library is the largest maintained by any professional organization and has a world-wide reputation. To it come daily questions from all parts of the world, from engineers in search of information on every kind of professional question.

The collection has grown steadily from 62,000 volumes in 1914 to 145,000 in 1935, an increase of 114 per cent, and the number of persons using it has increased even more substantially from 14,000 in 1914 to 41,000 in 1934, almost 3-fold.

Probably no library has more widely scattered users or does more of the work by mail. Engineers in 45 states and 21 foreign countries were helped by loans of books, copies or translations of articles, or by direction to the literature upon the subject in which they were interested.

One fourth of those who consulted the library in 1934 did so by correspondence without ever setting foot inside the building. This is important in that it shows that the benefits of the library are not confined to those in New York City.

The cost of operating the library in 1934 was $48,500, of which the founder societies contributed only $30,000, or 60 cents per member. $8,500 was earned by special services and the remainder came from our small endowment. There was added to the collection 4,100 volumes, moderately appraised at $15,000.

The yearly increase in the money value of the library is an item to which I call your attention, as few realize that we are gradually building up a quite considerable capital investment which is now appraised at $500,000. Not all the money we contribute to the library is gone for good. We have something tangible to show for some of it.

Our library is well catalogued and indexed with 476,000 cards, which condition makes it easy for any individual to find what he wants.

There are great possibilities for work with the industries of the country and for great advantages to manufacturers. For this to be realized, however, it will be necessary for the industries to assume some responsibility for the support of this agency which they use so freely. To expect the whole burden to be borne by the engineer as an individual may have been proper in the day when the engineer was an independent professional man; today when so many engineers are employees of large corporations, these corporations should provide library facilities as they provide other business requirements. This they can do in the most effective way by building up the Engineering Societies Library to even greater effectiveness.

Of late there has been a desire for closer co-operation between the library and the membership of the societies living at too great a distance to be able to visit the library in person. To meet this desire we started some years ago a circulating library to which any member of the 4 founder societies may apply for any book that is purchasable. If we have not the book in our auxiliary collection we purchase it, send it to the member and charge a reasonable rental. In this way we are building up a lending library with no expense charged to our budget because it is self-sustaining. It should be understood that no library lets any "only" copy of a volume leave the building.

We now desire to enlarge our usefulness to our distant membership and have 2 new plans on foot to accomplish it.

The first, which is in process of being put into effect, is to encourage and assist the public libraries in the various towns and cities, to provide better facilities for the engineers of the neighborhood. This will be accomplished by making up a list of highly useful and desirable books and arranging that every librarian gets a copy, and incidentally to encourage the individual librarians to call upon us for help, advice and suggestions in building up their engineering sections.

The second proposal is to build up a more ambitious auxiliary lending library of the books most useful and generally in demand, and lend these on request by mail. This will require capital for the purchase of the books and operating expense to administer the system for the best interests of all concerned. It is a plan which we hope to put into execution as soon as financial conditions make it possible.

The Engineering Foundation

By H. P. Charlesworth, Chairman

A little over 20 years ago our beloved associate, Ambrose Swasey (HM'28) of Cleveland, Ohio, conceived a great undertaking for the benefit of the engineering profession and of aid in human advancement. In 1914 as a result of this high purpose and through

An Outline of the 8 Joint Functional Organizations

The 4 "founder societies," all having headquarters in the Engineering Societies' Building, New York, N. Y., with their dates of organization are: American Society of Civil Engineers, 1852; American Institute of Mining and Metallurgical Engineers, 1871; The American Society of Mechanical Engineers, 1880; and American Institute of Electrical Engineers, 1884. These founder societies jointly sponsor 8 functional organizations of national scope. An outline of these functional organizations, listed in order of establishment, and including definition, functions or activities, and personnel, follows:

1. United Engineering Trustees, Inc., 1904

The holding corporation and administrator of joint real estate and financial affairs for the founder societies. A national foundation for "the advancement of the engineering arts and sciences in all their branches."

The board of trustees (including all members of the corporation) exercises the powers and performs the functions of the corporation. There are 12 trustees, 3 appointed by each founder society. The board has a finance committee and a real estate committee. It manages various "funds."

General manager and staff operate Engineering Societies Building.

The corporation has 2 departments, Engineering Societies Library, and The Engineering Foundation. It is permitted to have others.

2. Engineering Societies Library, 1913 (Department of U.E.T., Inc.)

A free public engineering reference library, having one of the most comprehensive, carefully selected and best organized collections in the world of information on engineering and related sciences and history.

The library answers request for information by visitors and correspondents; makes searches on specified subjects; compiles limited or comprehensive bibliographies; translates articles from or into any language; makes abstracts; makes photostatic copies of articles or books; lends books by special arrangement; reviews books; advises on selection of books; manages publication of *Engineering Societies Monographs*.

Serves inquirers throughout the United States and in many countries.

Library board: 3 members designated by each founder society, 3 members-at-large, one trustee, secretaries of founder societies, director of library; total, 21.

3. The Engineering Foundation, 1914 (Department of U.E.T., Inc.)

An institution "for the furtherance of research in science and engineering, or for the advancement in any other manner of the profession of engineering and the good of mankind."

Its endowment funds are held and managed by U.E.T., Inc. The Foundation board has discretionary power in the disposal of moneys received from the board of trustees or other sources.

The Foundation aids the support, organization, and co-ordination of selected researches in engineering and related sciences, including economics and the human aspects of engineering.

Foundation board: one trustee from each founder society, 2 members nominated by each founder society, 3 members-at-large, the president of U.E.T., Inc.; total, 16.

4. American Standards Association, 1918

An association providing means for industries, technical organizations, and governmental departments to work together in developing acceptable national industrial standards and to prevent over-standardization.

Preliminary studies, determination, and publication of standards for engineering and industrial materials, equipment, tools, processes, products, and practices.

Composed of member-bodies, associate members, company members, and individual members. Board of 16 directors. The Standards Council, 117 members and alternates.

5. Division of Engineering and Industrial Research of N.R.C., 1919

One of the 7 divisions of science and technology of the National Research Council.

Functions: to encourage, initiate, organize, and co-ordinate fundamental and engineering research in the field of industry; to serve as a clearing house for research information of service to industry.

Division has 27 members representing the founder societies, American Society of Refrigerating Engineers, American Society for Testing Materials, American Society for Metals, American Society of Heating and Ventilating Engineers, Illuminating Engineering Society, Western Society of Engineers, Society of Automotive Engineers, American Welding Society; 3 members-at-large, and the chairman; total, 31.

6. Engineering Societies Employment Service, 1919 and 1923

A service supported by the founder societies to aid their members in obtaining employment or in finding engineering assistants. Offices in New York, Chicago, and San Francisco.

Registration and placement of engineers and engineering assistants; service to employers of engineers.

Board: the secretaries of the founder societies.

7. American Engineering Council, 1920

A central agency to further the public welfare wherever technical and engineering knowledge and experience are involved, and to consider and act upon matters of common concern to the engineering and allied technical professions.

Comprises 220 groups of organized engineers located in 41 states, including 7 national societies (202 local sections), 4 independent state societies, and 14 local societies.

A service unit providing a clearing house for information, a forum for deliberation, and a means of giving national expression, through 12 standing and special committees, to the aims of the engineering profession as a whole, dealing with relations of engineers to the public and to governments in matters of engineering content.

Membership of annual assembly, held in Washington, D. C., 36 representatives of the constituent member bodies.

8. Engineers' Council for Professional Development, 1932

A conference of engineering bodies organized to enhance the professional status of the engineer through the co-operative support of those national organizations directly representing the professional, technical, educational, and legislative phases of an engineer's life.

Enhancement of the professional status of the engineer. Vocational orientation of prospective engineering students. Formulation of criteria for colleges of engineering. Plans for further professional development of engineering graduates and of nongraduates, devising methods whereby engineers attaining suitable standards may receive corresponding recognition. Acts as agent to effect these objectives when so designated.

Constituents: the founder societies, American Institute of Chemical Engineers, Society for Promotion of Engineering Education, National Council of State Boards of Engineering Examiners.

his generosity, there came into being The Engineering Foundation.

Beginning in that year, Doctor Swasey made the first of 4 gifts to the founder societies as a "nest egg" for nucleus to which other persons would add to build up a great endowment. Recognizing the advantages of utilizing the facilities of an organization already established for carrying on the joint undertakings of the societies, the fund was entrusted to United Engineering Trustees, Inc., and The Engineering Foundation was organized as a department of this corporation, but given full discretionary powers.

The Foundation is unique in many respects. It is so far as I know, the only institution of its kind in the engineering field. It is composed of representatives of the founder societies instead of being a closed self-perpetuating group. Its charter has been wisely chosen to safeguard its perpetual existence by giving wide latitude of operation to conform to changing conditions as time goes on. Doctor Swasey in his wisdom did a very important thing in making this charter so simple and by making it possible for succeeding generations to modify, as they saw fit within the broad limits of its purpose, the conditions under which it should from time to time operate. By the nature of its organization it will at all times have at its command the voluntary and supreme efforts of outstanding men from our engineering ranks to administer this great trust in behalf of the profession and mankind generally.

To assure the continued usefulness of the fund, the objectives and functions were stated in very broad language. The Engineering Foundation devotes its resources to human as well as technical aspects of engineering problems of wide interest. It aids the selection or initiation of projects most likely to advance the profession in its service to the public. Proposals recommended by the founder societies are given preference, other things being equal.

The Foundation endeavors within its sphere of influence to effect co-ordination of research and related activities and avoid duplication of effort wherever practicable.

The Foundation resources have been a growing endowment yielding $5,000 income in 1915 and $40,000 in 1934. An additional $230,000 in contributions have passed through its accounts. Also, a large total in money and materials has been contributed by co-operating bodies as well as the services of outstanding engineers and scientists who have served on boards or committees or individually.

The Foundation has no laboratories nor research staff. Needed facilities and personnel have been furnished by colleges or other existing establishments for carrying on the research it sponsors or assists.

It has been the founder's conception that the Foundation should not be merely an allocator of grants but should also initiate large projects of broad interest.

Being an instrumentality of national societies, the Foundation aids undertakings of benefit to our whole country. Some have been beneficial in many countries. It has selected capable agencies on the West Coast, in the Mountain Region, the Central Valley, the Lake Region and on the Eastern Seaboard. Universities, governmental bureaus, trade associations, industries, bankers, technical and scientific societies and numerous individuals have co-operated.

The assistance rendered by Foundation to various activities has been directed along lines which would, so far as practicable, sighted business and engineering judgment looking to the adaptation of technical progress to human advancement. Engineering Foundation aids in these matters wherever practicable. Important ways in which The Foundation functions in connection with these activities are (1) assisting in the development and training of men, (2) promoting important worthwhile projects (3) fostering co-operative projects, this being increasingly important in the growing complexity of science, engineering, and industry, and (4) aiding in the actual organization of co-operative groups and starting them into effective action.

Foundations are known by their deeds. The following examples attest the scope, variety, and range of magnitudes of undertakings which the Foundation had aided or carried on in the 20 years since its board organized in April 1915:

Educational and Sociological

Assistance in establishment of National Research Council, Highway Research Board, Personnel Research Federation, Engineers' Council for Professional Development.

Publication of *Research Narratives*, other pamphlets and books.

Betterment of engineering education through investigations of institutions, methods, and needs; summer schools for engineering teachers; production and distribution of the guidance booklet, "Engineering: a Career—a Culture."

Ten "Courses for Disengaged Engineers," on technical, financial, and personal subjects, given to 600 engineers in the Engineering Societies Building.

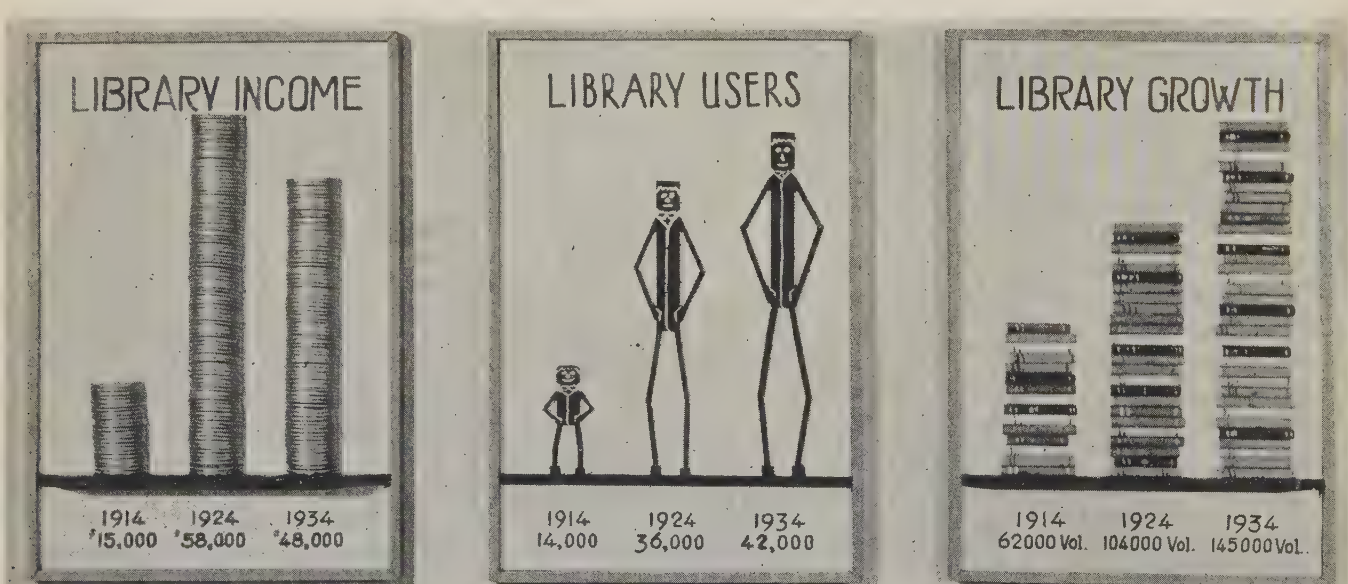
Technical Researches

In civil engineering, investigations of arch dams, earths and foundations, concrete and reinforced concrete arches, plastic flow of concrete, steel columns, hollow-crested weirs.

In mining and metallurgy, collation of knowledge of mining methods; researches in blast furnace slags, barodynamics, alloy steels and irons.

In mechanical engineering, properties of steam, lubrication of machinery, strength of gears, use and care of wire ropes for lifting and hauling effect of temperature on metals, metal cutting.

In electrical engineering, studies of insulation and fundamentals of dielectrics, and welding research, the latter being developed into a co-ordinated, comprehensive program.



A quickly visualized record of the dollar income, number of users, and growth in size of the Engineering Societies Library since 1914

activities for "the furtherance of research in science and engineering and the advancement in any other manner of the profession of engineering and the good of mankind."

The Foundation board has discretionary powers in its use of the income from funds held by United Engineering Trustees or from other sources. Its principal duty is bring to the undertaking other contributions of money or services.

The results of competently directed research are constantly needed to satisfy the demands of advancing civilization for greater and more efficient structures, for machines and processes. Also, there exists the need for independent thought and far-

The Foundation's work enriches human life. Knowledge gained flows through 4 principal channels: the engineering colleges,

by teaching and reports of research; the profession, by practice; the industries, public utilities and public works, by supply of community needs; the engineering societies, by meetings and publications.

The benefits of these and other activities have been great and far reaching. In the 20 years since the Foundation was organized there has been a steady growth in appreciation of the great usefulness and possibilities of this institution, through which the co-operative activites of scientists, engineers and industrialists can contribute to research and in other ways to the advancement of engineering and the good of mankind. Great as have been the contributions already made, we are confident that they mark but the beginning of far greater services to be rendered by the Foundation in the future.

American Standards Association

By Howard Coonley, President

When small groups of engineers began more than 20 years ago to discuss informally the organization of an activity which was destined to become the American Standards Association, I doubt that even the most far-sighted of them could have foreseen that more than 3,000 technologists and other experts would be working on more than 200 standardization and safety code projects now underway or in the process of revision.

The American Standards Association was organized in 1918 as the American Engineering Standards Committee by 5 major engineering societies—the mechanicals, electricals, civils, and mining, and the American Society for Testing Materials. Two years later several government departments and bureaus became "member-bodies."

The standardization movement in this country was given its first great impetus during the World War, when mass production of ordnance and war supplies of all kinds brought about the regeneration in manufacturing which has made the United States the greatest manufacturing nation on earth. Interchangeability, a corollary of mass production, demands standardization of measurements and tolerances. Component parts of various kinds of war equipment produced in New England, the Atlantic Seaboard and Mid-Western manufacturing states had to be interchangeable.

This natural and logical movement toward standardization was then organized by industry to serve its ends. Starting as it did in machine shops with screw thread standards, fits, and industrial safety codes, it has outgrown the narrower confines of the shops into every major manufacturing industry and into the homes of consumers, and today American Standards and Safety Codes are used in every state of the union.

But the functions of the American Standards Association remain the same today as when the American Engineering Standards Committee was first organized. It is the central clearing house for American Standards and Safety Codes. Any national group may bring standards or safety codes projects to the American Standards Association and the Association will undertake to organize the projects under its procedure and determine whether industry and the consumers interested really want the work carried on.

Because no standard or safety code is worth the paper it is printed on unless a substantial majority of interested groups are willing to use it, the function of determining a consensus is one of the primary purposes of the organization. This also means that every group that may have an interest or a stake in the proposed project must be invited to send its representatives to co-operate in working out the standard.

The organization went through a major reorganization in 1929 when the old American Engineering Standards Committee was changed into the American Standards Association. Today the Association is going through another reorganization which again will refine certain details of its operation to fit more perfectly into the changing industrial and economic picture of the nation.

But to those of us interested in the standardization movement, one important phase is striking. Through these 2 reorganizations no reason has been found to change the fundamental functions of the Association. Today, as always, a democratic forum must be maintained for variant points of view, and a consensus is just as essential today as ever before. Obviously, with the wider ramification of industrial activities, democratic representation is more difficult to achieve and agreement offers more problems than ever before. The changes in the Association's set-up are simply calculated to expedite work without jeopardizing the right of industries, and consumers and governmental agencies to present their respective cases in court. The sectional committees, which might be termed the lower courts, and Standards Council, to carry the analogy a little further, the higher court, are made up of manufacturing, distributing, and consumer groups interested in standards and safety codes.

In passing, let me say that nearly a half of the 524 approved NRA codes carry standards provisions. Several hundred of these include safety codes, many of which were developed through the American Standards Association and represent the approval of technical societies, manufacturers, consumers and interested governmental agencies.

A large number of states of the union have written American Standard Safety Codes into their regulatory provisions. Our work on building codes, now under way, will carry the work of the Association into every hamlet and city in the nation.

The reorganization of the Association recommended by our committees provides for a closer co-ordination of the individual fields of standardization which are now under way and which we expect will be undertaken if, as, and when industrial, consumer, or governmental groups initiate other projects. That is all.

Thirty-nine national associations are represented by 35 "member-bodies" on the Standards Council, which finally approves American Standards and Safety Codes. An additional 11 national groups are represented by 10 "associate-members." 3,000-odd technical experts represent the points of view of about 600 national groups. These include a number of governmental departments and bureaus.

Our Association is a member of the International Standards Association. This gives American industry representation in the standards forum of 19 nations of the world.

For the past 6 years I have been interested in the work of the American Standards Association, representing the American Society of Mechanical Engineers. I can honestly say that the range of activity is many times as large today as when I attended my first meeting as a new member of the board. And we are on the threshold of a vista which baffles my imagination as I see more and more groups interested in the national standardization movement. Each comes to us with a problem which holds the answer to some important economic question involving other industries and groups.

Conversely, some of these problems cannot be met and dealt with without these impingent groups also becoming active in the work. This is expressing our membership problem from the viewpoint of our own present membership. In this broader aspect we have the support of many industrial leaders of the country who have personally given impetus to our membership campaign.

As long as industry has the machinery to adjudicate its own problems, we can resist inroads contemplated by government. The machinery of the American Standards Association has been tested for a long time, and it works. Today we are gearing it to an accelerated pace, to perform the duties and the obligations which will be imposed upon us tomorrow by manufacturers, distributors, and consumers.

Division of Engineering and Industrial Research, N.R.C.

By D. S. Jacobus, Vice Chairman

The purposes of the division of engineering and industrial research of National Research Council are to encourage, initiate, organize, and co-ordinate fundamental and engineering research in the field of industry, and to serve as a clearing house for research information of service to industry. In its primary functions the division attempts to maintain a balance between: (1) the demonstration of research methods and techniques through large, national research projects representative of the major fields of engineering; (2) the promotion of research in the field of industry, largely through trade associations by such methods as addresses, literature, meetings, conferences, radio talks, research laboratory inspection tours; and (3) a research information service.

By its plan of organization as part of the National Research Council, the division is especially fitted to bring together scientists and technologists, able and willing to contribute the variety of knowledge and experience requisite for successful attack on research problems. Its quasi-governmental status makes it possible to obtain the co-operation of the various departments of the government, universities, technical societies, other divisions of the Council. Industrial co-operation has been utilized to an ex-

tent which would not be obtainable by many organizations. In a national emergency, National Research Council stands ready as a national advisory service organization to mobilize scientific, engineering, and technical resources for the public interest.

As a division of National Research Council, the division of engineering and industrial research is unique in organization and flexible through co-operative relationships. Division membership is largely comprised of representatives from national engineering societies. It co-operates with Engineering Foundation, which furnishes it office space in the Engineering Societies Building. Engineering Foundation has assisted National Research Council, as well as the division, in many ways. The division is in touch with the 1,600 industrial research laboratories in this country; and also in correspondence with 100 laboratories in the principal research centers abroad. Its varied activities are designed to maintain constant contact with universities, trade associations, and private research laboratories.

The division depends upon interested industry for support of specific research projects. The division's administrative expenses are paid from endowment funds of Research Council.

Research committees and projects demonstrate successful utilization of research methods, techniques, and apparatus, and selection of personnel. Stimulation of research by selected projects in fields of engineering and industry follows the general policy of National Research Council. Yardsticks to evaluate projects before they are undertaken have been developed. In organizing research committees 3 types of personnel are drawn upon: scientists to lay out the research program, engineers to develop tests, industrialists to direct industrial applications.

The Highway Research Board demonstrates the functional operation of the division. In this project 4 essential functional features are combined:

1. A national clearing house for highway research data.
2. Co-ordination of federal highway research activities with state research activities.
3. Development of new university research centers in the highway field.
4. Distribution of highway research abstracts to stimulate industrial research and eliminate duplication.

Other division projects include electrical insulation, heat transmission, industrial lighting, and relationships between university research and industry. Each of these projects in its development has operated through the whole gamut of functional purposes in initiating research, encouraging research, effecting co-ordination, and eliminating duplication.

The annual proceedings of the electrical insulation committee examplifying international interest which appear in the American Institute of Electrical Engineers' publication ELECTRICAL ENGINEERING are closely followed by technologists abroad.

Promotion of industrial research requires experimentation to develop effective methods. The trade association has proved to to be the most effective channel to reach an industry as a whole. Records of current industrial research activities of representative industries have been compiled, catalogued and studied to develop opportunities for service. Oftentimes a leading trade journal takes the initiative in starting a campaign for research. After conferring with those in the industry who are particularly interested, the division recommends the appointment of a small research committee. Research committees have been taken on a tour of inspection to successful research laboratories operating in the same or closely allied fields of industry. The division continues to serve in an advisory capacity if requested.

Some industries with which the division has successfully developed co-operative research activities include: brick and clay, chemical, combustion utilities, fisheries, gas, glass container, lithographic, porcelain enamel, cotton textile, and commercial aviation.

An average of 30 articles and addresses a year are prepared and delivered by officers of the division. The resulting action has been evaluated in terms of division objectives. The comparative effectiveness of the address, article, popular science radio broadcast, motion picture have been developed as implements for promotion of research.

A committee on relationship between university and industry was organized to hold 8 regional university conferences. The primary purpose is to bridge the gap between university and industry research. University contacts with industrial laboratories were established. Through such a common pool the resources, facilities, and personnel of universities' laboratories are made available to specific research needs of industry.

Actual demonstrations of research organization and operation were sought by many executives who contemplated establishing research laboratories or expanding them. Two inspection tours of representative research laboratories for a select number of executives and bankers were organized and conducted under division auspices. The first tour exemplified research as conducted by large industrial companies, and the second was through smaller laboratories.

Two unusual projects deserve mention to demonstrate the division's strategic position as a flexible mechanism in organizing and mobilizing scientists and engineers for national and international movements. The American committee of the World Engineering Congress held in Japan in 1929–30, was organized by the division in co-operation with the national engineering societies; and through the congressional charter of the National Academy of Sciences the Council arranged for a number of the members of the American committee to participate in the congress. A representative group of distinguished engineers and their families numbering 225 attended; 80 papers covering significant engineering achievements were presented. The other project was the assisting in the formation of a science advisory committee for the Chicago "Century of Progress" exposition, and 34 sub-committees. The division gave assistance to the central office of National Research Council and to the science advisory committee during the 2 years activity of the exhibition.

An increasing volume of inquiries on all research subjects makes it necessary for the division to be geared to shifting trends in research. Surveys are continually being made to obtain facts from industry on research expenditures, types of problems, significant trends and emphasis in research programs, trade association research, and the effect of the depression on research activities. This material is published and distributed by the division to libraries, trade associations, government bureaus and foreign laboratories. Research data have been supplied to research directors to assist in presenting a case to their boards of directors to maintain research appropriations.

A supplementary activity of the division is the administration of grants in aid in engineering and industrial research. Some fields covered by National Research Council grants-in-aid include welding, electrical insulation, radio, highway, and cement. Recent policy from Council headquarters, after consultation with the division, indicates that grants-in-aid will only be available in engineering and industrial research, where the lack of industrial support is demonstrated.

To aid in the National Recovery Administration, President Roosevelt issued an executive order creating "a science advisory board with authority, acting through the machinery and under the jurisdiction of the National Academy of Sciences and the National Research Council, to appoint committees to deal with specific problems in the various departments." The division of engineering and industrial research has continuously served the science advisory board since its inception. It has materially assisted in development of such projects as co-ordination of railroad research, decentralization of industry, patent system as related to new industries, technological reports of foreign commerce officers, radio signaling to avoid collision in fog at sea, and co-ordination of scientific and technical activities in the department of commerce.

Engineering Societies Employment Service

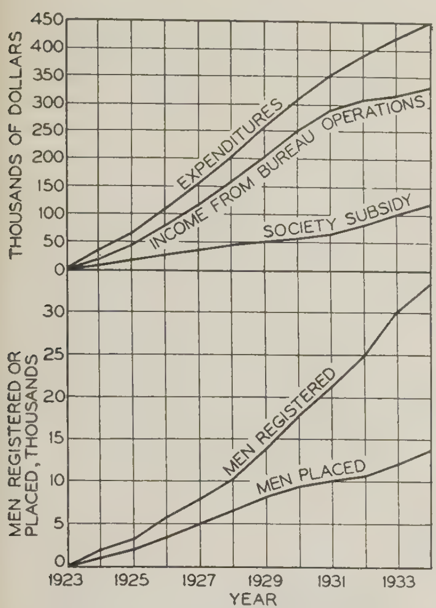
By George T. Seabury, Chairman, National Committee

The first joint effort of the engineering societies in the establishment of an employment office was in 1918. The service was managed by a board made up of the secretaries of the 4 founder societies, and the funds for its maintenance were provided by the societies. Prior to 1918, each of the 4 national engineering societies had operated free employment services to their members for various periods. On January 1, 1921, the management of the bureau was taken over by the Federated American Engineering Societies (now American Engineering Council) and was known as the Employment Service for that organization.

Later, in 1923, the management was taken over by the founder societies, the boards of direction inaugurating a new policy respecting the service. This action was based upon the report of a joint committee, representative of the 4 societies, which recommended among other things a co-operative plan of operation. Under this new arrangement, free service was discon-

tinued in favor of a plan to be financed in part by the societies and in part by those who benefited in having received positions through the efforts of the service.

This plan also called for the establishment of offices throughout the country as conditions permitted so that in time the service might become more truly national in scope.



A summary of the operations of the Engineering Societies Employment Service over the $11^1/_4$ years of its existence previous to 1935

All values are cumulative totals since beginning operation the later part of 1923

Pursuant to this policy, an office of the service was opened in Chicago in 1925 which was administered by representatives from the local sections of the founder societies in Chicago in co-operation with the Western Society of Engineers, which assisted in its financial support. Another office was opened in San Francisco in 1926, this office being administered by representatives from the local sections of the founder societies in San Francisco and in financial co-operation with the California Section of the American Chemical Society and the Engineers' Club of San Francisco.

The New York office differs from the other 2 offices in that its administration has been assigned to the assistant secretaries of the 4 societies.

The direction and management of the several offices of the employment service as a whole is under a board consisting of the 4 national secretaries. This board allocates the funds to each of the offices in accordance with the needs, sees that the policies as established are carried out, and otherwise acts as the executive head for the entire joint enterprise.

Use of the service is confined to the members of the 4 national societies and co-operating organizations. The establishment of 3 offices has enabled an exchange of positions and the publication of bulletins of positions available for the use of members seeking opportunities, thus accomplishing in part the making of the service more truly nationwide.

In normal times, the employment service is self-supporting and in exceptionally good times, such as prevailed from 1927 to 1929, the Service was able to build up a surplus to help meet such conditions as have prevailed since 1930. During the past 5 years there has been a dearth of employment opportunities and a great reduction in the normal income received through placement contributions with the result that this surplus has been exhausted and a large proportion of the cost of operating the 3 offices been borne by the founder societies.

Something of the effectiveness of the employment service may be gauged by the fact that for the $11^1/_4$ year period, from 1923 to 1934 inclusive, 33,372 engineers have been registered in the 3 offices, 28,721 positions have been received for filling, and 13,870 placements have been made.

This is indeed a remarkable showing when it is considered that about 25 per cent of the combined memberships of the founder societies have been assisted by the service upon one or more occasions. In view of the extent to which the employment service has served the members as well as the needs of employers in all phases of engineering and industry, it appears that this activity should be continued, improved, and expanded.

American Engineering Council

By John F. Coleman, President

The American Engineering Council was organized in November 1920, to act as a central agency for groups of organized engineers throughout this country. Its membership includes national engineering societies, representing various branches of the profession, and state and local engineering organizations. Council does not direct the activities of its members, but is a service unit providing a clearing house for information including employment sources, a forum for the deliberation of joint problems, and a means by which engineers may express themselves collectively on public problems.

Some 60,000 engineers are represented by the American Engineering Council, at the present time, through 7 national, 9 state, and 25 local societies.

We are rapidly establishing ourselves as the "Washington Embassy" of American engineers and engineering, and perfecting a nation-wide organization that will truly represent the profession. This is being done through state public affairs committees which are to function 2 ways: first, to engage themselves in local and state problems along the general lines of Council's purpose; second, to become corresponding committees on national policies which may grow out of the consideration of state and local problems.

State and local societies are showing a renewed interest in Council and some 15 new societies have joined or are in the process of joining under a membership plan which provides affiliation for a reasonable fee. Their connection with Council will strengthen the national professional organizations and also give the local groups an opportunity to participate in national questions in an organized and constructive way.

Council functions through committees of experienced men who study legislative measures and policies which effect both business and industry, and government agencies. They furnish advice and assistance to congressional committees and government agencies; and to business and industrial organizations on all questions or matters where it is evident that trained engineering minds may be of service.

Just now the federal and state programs are of first importance, but the majority of engineers are in private industry; therefore the development of technology in backward industries is considered the main field for the future growth of the profession.

Other objectives include the raising of the prestige and purposes of engineers in the public mind through a program of public education; and the clarification of engineering-economic purposes among engineers themselves.

Our officers firmly believe that there is a great need and a real opportunity to advance the engineering profession by promoting the purposes of functional organizations and establishing co-ordinated committees between existing agencies, rather than starting new societies.

We appreciate the wonderful co-operation we are receiving from the organizations which support us; and I personally wish to express my gratification at this opportunity for the exchange of ideas with those representing other organizations serving the profession.

I feel that each of our representative organizations is deriving advantage from co-operating with the others and it is sure that the most effective co-operation may be brought about by a clear understanding on the part of each of us as to what the other is trying to do.

Engineers' Council for Professional Development

By C. F. Hirshfeld, Chairman

The Engineers' Council for Professional Development is a comparatively new agency of the engineering profession, having been brought into being in October 1932. It was formed as a result of a very general recognition of 2 facts, namely:

(*a*) The time has arrived when engineering must take its place among the learned professions.

(*b*) The engineer must prepare himself for a greater and more extended degree of usefulness if he is to measure up to the demands that the present social structure is certainly preparing to place upon him.

The purpose of the E.C.P.D. is the enhancement of the professional status of the engineer. It aims to co-ordinate and promote aspirations and efforts directed toward higher standards of education and practice, greater solidarity of the profession, and greater effectiveness in dealing with technical, social, and economic problems.

The E.C.P.D. is necessarily a joint body because the purposes for which it was formed could not conceivably be achieved except through the most intense and sympathetic co-operation of national organizations representing several different interests in the profession. It consists of 21 mem-

bers, 3 appointed from each of 7 participating bodies:

American Society of Civil Engineers
American Institute of Mining and Metallurgical Engineers
The American Society of Mechanical Engineers
American Institute of Electrical Engineers
American Institute of Chemical Engineers
Society for the Promotion of Engineering Education
National Council of State Boards of Engineering Examiners

It is believed that the 5 first named represent adequately the major branches of the practice of engineering. The sixth obviously represents the educational interests. The seventh, a national organization formed by members of the boards set up by the different States for the registration of engineers, is obviously a necessary participant since it represents the increasingly important legal aspect of and legal responsibility of the profession. In growing numbers the States are enacting laws to give professional status to engineers meeting certain requirements with respect to education, accomplishment, and character.

The E.C.P.D. is not a self-continuing nor an independently acting organization. The members are appointed by the 7 participating bodies so that the latter always have it in their power to make its membership what they will. Further, it functions by studying questions within the range of its objectives and making recommendations to the governing boards of its sponsor bodies. Such recommendations are with respect to activities or procedures that it considers would be of value in enhancing the professional status of the engineer. It has no authority to undertake to do more than this unless specifically authorized to do so by those who formed it. Nor does it have authority to administer recommended procedures unless these have been approved by the governing boards of the participating societies and then specifically assigned to E.C.P.D. for administration.

Enhancement of the professional status of the engineer is a most intangible sort of thing. This very intangibility gives rise to many different views of the methods that might be pursued. The E.C.P.D. has taken the view that the soundest procedure is for the engineer so to improve himself and his capacity for service that he certainly will measure up to any demands that society may find it necessary or desirable to make upon him. It believes that the ability to serve adequately in professional capacity is bound to bring adequate professional recognition.

Such ideas make possible the preparation of a very definite program. Parts of this program already have been submitted to the governing boards of the participating societies; some of these have been approved and are now active projects.

The E.C.P.D. started by appointing 4 subcommittees, each charged with the study of a certain field of endeavor with instructions to report back to the E.C.P.D. These subcommittees are:

1. Committee on student selection and guidance.
2. Committee on engineering schools.
3. Committee on professional training.
4. Committee on professional recognition.

With the explanation that student selection and guidance refers to the entry to colleges of engineering, it becomes obvious that these subcommittees cover the entire span from the time the boy considers seriously his entry into a college of engineering until he has reached the full stature of a professional man.

The committee first named is under the chairmanship of Dean R. L. Sackett. Its function is to report to E.C.P.D. schemes for the educational and vocational orientation of young men with respect to the characteristics of an engineering education and the responsibilities and opportunities of engineers, in order that only those who have the high qualities, aptitude, and capacity required to obtain intellectual satisfaction therefrom may seek entrance to such courses.

The committee on engineering schools is chairmaned by Dr. Karl T. Compton. Its function is to report to E.C.P.D. means for bringing about greater and more effective co-operation between the engineering profession and the engineering schools as well as to report criteria for colleges of engineering which will insure to their graduates sound educational foundations for the practice of engineering.

The committee on professional training is under the chairmanship of General R. I. Rees. Its duty is to report to E.C.P.D. plans for the further personal and professional development of young engineering graduates and young men who are entering the profession without formal scholastic training.

The last of the subcommittees is headed by Conrad N. Lauer. Its function is to report to the E.C.P.D. methods whereby engineers who have met suitable standards may receive corresponding professional recognition.

All the subcommittees have already made reports to E.C.P.D. and the latter, as a result, has already made a number of definite recommendations of a constructive nature to the governing boards of the sponsor bodies. Some of these recommendations have received favorable action, others still are before one or more of the boards for consideration.

The engineer has done a marvelous technical job. He has in a comparatively short space of time converted the abstract findings of scientists to the practical use of man in an astounding profusion of technical inventions and their materialistic embodiments. He has, in fact, completely changed the tenor of human work and life. Even the man in the street appreciates a lot of what the engineer has done for him.

But the engineer has failed to take proper cognizance of the social and economic results of his works. He appears, in most cases, to have been content to devise and to execute in an altruistic spirit those material improvements which now stand to his credit without giving thought to the less materialistic but equally real problems that he was bringing into being. If he gave any thought to such matters at all, he appears to have believed that others would take care of them as their share provided he took care of his.

It now appears that we have failed to preserve a proper balance between inventions of 2 radically different sorts. Inventions in science and its application appear to have outstripped inventions of social and economic types. And, it appears that we shall have to make real efforts toward the restoration of a more nearly perfect balance if the works of the engineer are not to prove of less real value to the race than he has fondly hoped.

E.C.P.D. does not have any inflated notion of the engineer's abilities outside the technical field; but it does believe that the engineer is best able to interpret his own works. And it does believe that, if properly educated in extra-technical subjects, he can be of great assistance to those normally expected to make the social and economic inventions now so sorely needed. It does believe that the time has arrived when the engineer must expand the field of his activities while remaining technically sound and while continuing to consider the planning and execution of engineering works as his primary job.

The program of E.C.P.D. therefore visualizes the production of an engineer of much greater breadth of vision than has been customary in the past. It stands for the soundest sort of training in technical matters but aims at the same time to develop that broad appreciation of human problems that it feels necessary in the engineer of the future. By such a route it sees the engineer growing to full professional status and to full recognition as a professional man.

Semi-Centennial of Award of the First E.E. Degree

The Massachusetts Institute of Technology reports that on August 31, 1882, it announced its pioneer course, and on June 2, 1885, awarded the first electrical engineering degree in America. The event was celebrated at Cambridge, Mass., June 3, 1935, by a semi-centennial symposium in which electrical engineering education in the United States during the past 50 years was reviewed with particular reference to the influence which the Massachusetts Institute of Technology has had on its development.

The principal speakers were Dr. F. B. Jewett (A'03, F'12, and past-president) president of the Bell Telephone Laboratories, Inc.; Dr. A. A. Potter, dean of engineering at Purdue University; and Dr. Vannevar Bush (A'15, F'24) vice president and dean of engineering at the Massachusetts Institute of Technology. Professor D. C. Jackson (A'87, F'12, member for life, and past-president) head of the department of electrical engineering, presided.

Following the symposium a testimonial luncheon was held in the Walker Memorial for Professor Jackson, who retires this year after directing the electrical engineering division for 28 years. The speakers at the luncheon included Herbert G. Pratt, president of the Samson Cordage Works; C. A. Stone (A'91, M'07, and member for life), chairman of the board, Stone and Webster, Inc.; Gerard Swope (A'99, F'22, and member for life) president of the General Electric Company; Professor W. S. Rodman (A'07, F'28) dean of engineering at the University of Virginia; Professor G. C. Dahl (A'22, F'33) representing the electrical engineering faculty at M.I.T.; Dr. K. T. Compton (F'31) present of the Massachusetts Institute of Technology; and E. L. Moreland (A'11, F'21) who succeeds Professor Jackson as head of the department of electrical engineering. Professor Jackson responded,

and Alexander Macomber, consulting engineer and public utility executive, presided.

In the electrical engineering laboratories special demonstrations were made of calculating machines, electrical communication, sound measurement, modern illumination, developments in electronics, stroboscopic measurement, insulation research, electrophysiological research, and super high-voltage engineering. A statistical and historical exhibit will illustrate the development of electrical engineering education at M.I.T.

Tennessee Electric Power Company Receives Award. The annual award of the Charles A. Coffin Foundation, established by the General Electric Company in 1922, has been awarded for 1934 to the Tennessee Electric Power Company, of Chattanooga. The award, comprising the Charles A. Coffin gold medal, a certificate, and a check for $1,000 to be deposited in the treasury of the utility's employee welfare association, was received by Jo Conn Guild, president of the Tennessee company, during the recent annual convention of the Edison Electric Institute at Atlantic City, N. J., June 5. Faced with a difficult and competitive situation, the entire personnel of the company, under the leadership of its president, proceeded to develop one of the most unique sales programs ever carried out by a public utility, in the opinion of the judges. Every individual in the organization, regardless of his position, became a salesman for the company's kilowatt output. The award was made on the basis of substantial rate cuts, substantial increases in appliance sales, and a 26 per cent increase in residential consumption, all accomplished in the face of an unprecedented situation in the Tennessee Valley, partly affected by the work of the Tennessee Valley Authority. The company conducted well organized efforts to improve public relations, maintained safety activities, improved plant operation, and effected substantial engineering improvements in relaying. It co-operated in the sale of appliances with dealers, with the T.V.A., and with the E.H.F.A. The committee of judges consisted of T. N. McCarter, president of the Edison Electric Institute, K. T. Compton (F'31) president of the Massachusetts Institute of Technology, and F. W. Smith (A'05, M'12) *chairman*, president of the New York Edison Company.

American Engineering Council

Status of Government Construction Programs

Following are excerpts from the current "news letter" of American Engineering Council:

Administrators of government funds of the several agencies of government are scrutinizing with renewed care the exact phraseology of the legislation which gives them their authority. One immediate effect, therefore, of the hundreds which flow from the U.S. Supreme Court decision is to call attention both on the part of those who administer the work relief program and those who are expected to benefit by the work relief program, to its exact provisions. This re-defining of authority now taking place is further affected by the interrelations between state law and federal law on relief. This situation tends for further confusion in straightening out the organization and expenditure of the work relief program.

In A.E.C. items published in previous issues of ELECTRICAL ENGINEERING, the general status of the work relief measure and the amounts of the work relief appropriations have been given. Because of the confusion that exists both outside and inside of Washington at the moment, it seems worth while to restate the fundamental philosophy and purpose of the work relief bill for the benefit of engineers and engineering:

(*a*). This bill was conceived and passed to provide funds to employ 3,500,000 people for one year, heads of families now on relief. It was conceived as a relief measure primarily and not as an employment measure. The 4 billion dollars was established on the basis of actually averaging to pay a man on relief $50 a month. This sum is the approximate average allowance per head of a family of from $19 to $94 a month. This compensation for relief was purposely set at this relatively low figure so that men on relief would prefer jobs outside of relief, rather than to continue on types of work paid on a relief basis.

(*b*). The bill provides that this work shall be carried out within the locality of a man's present place of residence. In other words, local projects of such character that lend themselves to relief work would employ men and women on local relief rolls.

(*c*). The type of any given project is to be determined by the training and experience with the available relief labor within the locality of that project.

(*d*). This whole program is predicated on the intention that work relief shall be made unattractive.

(*e*). The bill includes provisions for administration expenses. The payment for such administration expenses is *not* on the basis of the relief compensation, but is to be established on the basis of the going local rates or fees for such work.

American Engineering Council has followed this program from its beginning. The staff of Council is familiar with the details of the program from its inception. The summary above in the long view represents our understanding not from newspapers' comments, but from an analysis of the law itself and of the executive orders so far issued.

The Recent Executive Committee Meeting of A.E.C.

The executive committee meeting of Council in New York, N. Y., May 20, 1935, covered a wide field of professional subjects. The water resources committee report prepared under the chairmanship of W. S. Conant, was approved. Two fundamental needs for a national water resources policy are named as: (1) complete and correlated data; and (2) comprehensive study of water control legislation. A federal bureau of water resources is endorsed in principle and an interdepartmental board of water resources investigations is recommended to correlate investigational functions of federal units. Extension of the work of the water planning committee is recommended through a national advisory water planning agency for comprehensive, integrated drainage basin planning.

As to legislation, it is pointed out that bills in Congress often stress the importance of water power beyond the other urgent needs for water; also overlook the known facts which limit the economic development of available power sites. Intensive study by engineers is therefore desirable.

Opposition to the establishment of additional river basin authorities along the lines of T.V.A. at the present time was adopted as a policy of Council.

Membership of state and local societies newly united with Council was approved; as were the new assembly members from these groups. It is planned to use the rating system of the Engineers' Council for Professional Development in determining the eligibility of members of the assembly. Procedure for handling new membership applications was simplified.

Other Items of A.E.C.

Cases are being studied where engineers who have qualified under civil service feel that the rating did not give them the guarantee of employment to which they are entitled. Arthur W. Berresford (A'94, F'14, and past-president), past-president of A.E.C., has begun a preliminary survey of the general relationship of engineers to the civil service.

Boards of civil service appeals, to settle differences between federal civil service employees and their superiors, are proposed in the Sirovich bill (H. R. 3980). On a 3-man board to hear a given case, one member would represent the employee, 1 the civil service commission, and 1 the federal unit involved in the dispute. An engineer could be represented by a delegate from his engineering society.

The Anti-Gasoline-Tax-Diversion Association has asked Council to support the idea of restricting gasoline taxes to highway purposes. The executive committee suggests that this will be a desirable project to refer to state public affairs committees when they are formed, but state and local societies need not delay action on their own initiative.

Council's support of a program of aviation research under the National Advisory Committee for Aeronautics was recommended unanimously by the A.E.C. committee on aueronautics and was approved by the executive committee. The desired program is set forth in a paper by Dr. Alexander Klemin, secretary of the A.E.C. committee. Copies are available on request. Briefly, the recommendation is that the N.A.C.A. receive $50,000 per year of federal funds earmarked for research

to be done by universities and other institutions of public standing; not for educational purposes, buildings, or basic equipment. Scientific workers at approved institutions desiring to do research would submit formal plans. Results would be published in the form of N.A.C.A. technical reports or technical notes. A committee representing the N.A.C.A., Army, Navy, and Department of Commerce would supervise.

Numerous patent bills were considered and Council's opposition to the Sirovich bill (H. R. 4523) for the registration of patent pooling agreements, previously voiced by the committee on patents, was confirmed by the executive committee.

Participation of Engineers in Public Affairs

As reported in previous letters, Council is working toward increased participation of engineers in public affairs through a plan which ultimately will result in the setting up of state and regional public affairs committees composed of keymen in each area. The system of membership committees, now rapidly developing to encourage state and local societies to join Council under the new plan of nominal dues, is a step toward the final network of organized groups. Each new member society is asked to appoint a man to keep Council informed as to public affairs in his region and a complete setup in 1 or 2 states in order to test the plan is being made.

Meanwhile, there is a preliminary phase in which all can help. It is the feeling of A.E.C. that, if engineers really are to bear weight in public affairs, the field must be developed along lines of engineering analysis just as the technique of the profession has taken form over the past several decades. There is now an extensive literature of engineering technique so that a specialist in any branch of the profession may read the record of successful experience in relation to his problems. But the equally broad field of public affairs has not been fully explored and charted by engineers. Council, therefore, is seeking to assemble material in an effort to build up a practical record of experience along this vital line of activity.

Individuals can help by sending in general observations as to the proper relationship of engineers to public affairs together with accounts of actual cases with which they are familiar.

News for State and Local Engineering Societies

Through the distribution of its monthly "news letter" and discussion contributed thereon A.E.C. is working toward a clearing house arrangement which will promote a quick exchange of thought between the widely separated engineering groups throughout the country. Discussion of "news letters" is encouraged. The following items will suggest the type of suggestions desired.

A committee on educational economics has been organized by the Grand Rapids Engineers' Club to analyze the expenditures for heat, light, and power in the local schools, at the request of the board of education.

Engineering fairs, held by colleges or otherwise, are a means to acquaint large numbers of people with technical progress and to give the engineers themselves an insight into developments among the many specialized branches of the profession.

At the University of Washington, a biennial open-house is sponsored by the Engineers' Council.

An industrial museum and library are being promoted by the Engineers' Society of Milwaukee, which is also investigating the possibility of securing federal funds so as to proceed under a professional work-relief project.

If suggestions or material for speeches within the field of Council are wanted for use at meetings, write to the A.E.C., 744 Jackson Place, Washington, D. C. State and local societies, whether or not members of Council, are requested to keep Council up to date on officers, boards of direction, announcements of meetings, and other matters of interest so that the profession can be kept advised as to what is going on.

Standards

New Committee Organized on Electric Magnitudes and Units

Dr. A. E. Kennelly (A'88, F'13, HM'33, past-president, and member for life), professor emeritus of electrical engineering, Harvard University, was elected chairman of the new Sectional Committee on Electric and Magnetic Magnitudes and Units, and E. C. Crittenden (A'19, M'22), assistant director, National Bureau of Standards, was elected vice-chairman, at the organization meeting of the committee in the Engineering Societies Building, May 2. J. W. McNair, Electrical Engineer of the American Standards Association, was elected secretary of the committee.

The new sectional committee, which is working under the sponsorship of the Electrical Standards Committee of the American Standards Association, replaces a former special committee of the U.S. national committee of the International Electrotechnical Commission, the sole function of which was to advise the U.S.N.C. of opinion in regard to international standardization work on electric and magnetic magnitudes and units.

A subcommittee, of which E. C. Crittenden was elected chairman, was authorized to study and report upon fundamental systems of equations and units as employed in the sciences of electricity and magnetism. The subcommittee will thus explore the entire field of electric and magnetic magnitudes and units to see if it is possible to recommend a single system of electric and magnetic magnitudes and units for use by physicists to replace the present rather confused situation involving several systems.

The sectional committee also will collect in the form of a single pamphlet all of the decisions which have been made in the past by the International Electrotechnical Commission in respect to electric and magnetic magnitudes and units in order that they may be available to authors and workers in the field. Such of the decisions as appear to be suitable for American adoption will be considered by the sectional committee, with a view to recommending them to the American Standards Association for approval as American Standard.

The membership of the new sectional committee includes all of the members of the former special committee, together with representatives of other organizations. This new representation was provided because, in order to comply with the basic principles upon which sectional committees of the A.S.A. are organized, it is necessary to have representation from all concerned with the subject.

Members of the committee and the organizations they present are:

A. E. Kennelly (A'88, F'13, HM'33, past-president, and member for life), American Institute of Electrical Engineers, *Chairman*

E. C. Crittenden (A'19, M'22), National Bureau of Standards, *Vice Chairman*

J. W. McNair (A'25), American Standards Association, *Secretary*

American Institute of Electrical Engineers, A. E. Kennelly, C. H. Sharp (A'02, F'12, and member for life), W. I. Slichter (A'00, F'12, member for life, and national treasurer), V. Karapetoff (A'03, F'12, and Life Member)

American Association for the Advancement of Science, A. P. Wills.

American Institute of Physics (to be appointed later)

American Society for Testing Materials, H. L. Curtis (A'21, F'26), W. J. Shackelton

A.S.A. Electric Light and Power Group (to be appointed later)

A.S.A. Telephone Group, W. J. Shackelton (A'12), H. S. Osborne (A'10, F'21)

Institute of Radio Engineers, J. H. Dellinger

National Bureau of Standards, E. C. Crittenden

National Electrical Manufacturers Association, J. J. Smith, I. M. Stein (A'18, M'27), R. E. Hellmund (A'05, F'13), W. N. Goodwin, Jr. (A'06, F'13)

National Research Council, Leigh Page

Society for the Promotion of Engineering Education, Harold Pender (A'06, F'14), C. V. O. Terwilliger (M'25)

The membership of the subcommittee will be selected.

Engineering Foundation

A Survey of the World's Welding Literature

Engineering Foundation has appointed a welding research committee to: (*a*) initiate and conduct a critical review of world welding literature; (*b*) render modest aid to worthy individual projects functioning under the fundamental research committee of the American Bureau of Welding; and (*c*) sponsor specific research investigations. The project will be started by funds contributed by Engineering Foundation supplemented by funds and services supplied by

industry. The project is jointly sponsored by the A.I.E.E. and the American Welding Society. (A previous announcement of this project was made in ELECTRICAL ENGINEERING for May 1935, page 571.)

Among the first proposed activities of the committee is a canvass of industry for the purpose of determining what services can be counted upon by the committee in the formulation of a program which will most effectively utilize the total of the resources which will be available to it. These contributed services will doubtless be of various kinds: reviews of literature and translations of foreign language articles which have been or are being made for private purposes; technical assistance, materials, and the loan of apparatus in connection with specific research investigations; and unpublished research data. A maximum of contribution in the form of such services can be made by industry at a minimum of additional cost.

It is also proposed to collect information from which can be prepared a list of research projects now under way and being planned that can be made available to the committee. Suggestions will be solicited for research projects which are recommended for prosecution under co-operative auspices. Another plan being considered is the setting up of a clearing house for translations and abstracts dealing with welding literature so that unnecessary duplication may be avoided and a maximum of co-operation secured in the critical abstracting of such literature.

The personnel of the committee is as follows: C. A. Adams (A'94, F'13, past-president and member for life), Harvard University, *chairman;* William Spraragen (A'17, M'26), American Welding Society, *secretary;* J. H. Critchett, Union Carbide and Carbon Research Laboratories; J. J. Crowe, Air Reduction Sales Company; H. M. Hobart (A'94, F'12, and member for life), General Electric Company; D. S. Jacobus (A'03), Babcock and Wilcox Company; G. F. Jenks, Ordnance Department, U.S. Army; and F. T. Llewellyn, United States Steel Corporation. Communications should be addressed to William Spraragen, American Welding Society, 33 West 39th Street, New York, N. Y.

Letters to the Editor

CONTRIBUTIONS to these columns are invited from Institute members and subscribers. They should be concise and may deal with technical papers, articles published in previous issues, or other subjects of some general interest and professional importance. ELECTRICAL ENGINEERING will endeavor to publish as many letters as possible, but of necessity reserves the right to publish them in whole or in part, or to reject them entirely.

STATEMENTS in these letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the American Institute of Electrical Engineers.

A New Source of "Kilocycle Kilowatts"

To the Editor:

I was much interested in L. D. Miles's article entitled, "A New Source of 'Kilocycle Kilowatts,'" which appeared in ELECTRICAL ENGINEERING, March 1935, pages 305–7, since some years ago we had occasion to set up and use a similar device in the Westinghouse research laboratories. This kilocycle power supply was used for determining the iron losses in thin laminated material for a range of frequencies from 3,000 to 50,000 cycles. The results were described in "High Frequency Iron Losses" by Thos. Spooner, published in the JOURNAL of the A.I.E.E., volume 39, Sept. 1920, pages 809–13. The tube consisted of 2 spherical tungsten electrodes mounted on stems, much as shown by Mr. Miles, in an atmosphere of hydrogen and mercury vapor. A 500-volt commercial d-c supply was used as a source of power. For this particular application a sine wave of current was desirable so a double tuned circuit was set up instead of the single oscillating circuit shown by Mr. Miles.

We found this device very useful as a laboratory tool but did not feel that it had much value for commercial application due to its rather low efficiency. Mr. Miles's article would have been much more valuable had it not been for a number of omissions of pertinent information. To illustrate, what is the function of the third electrode shown in figure 1; this is neither mentioned in the text nor indicated in the diagram of figure 2? What is the most suitable gas and pressure for a tube of this kind? Why cannot the magnetic field and choke of figure 2 be combined into one unit? Is the magnetic field coupled with the tube? What is the minimum d-c voltage required for satisfactory operation and also what is the inductance necessary in the input circuit? In figure 4 is the large coil in the foreground the choke or the magnetic field? What is the device mounted behind the 3 single pole knife switches and what is the function of the 3 single pole knife switches? What is the maximum efficiency obtainable with a device of this kind? Finally, since the larger outfit described has only 500 watts output the use of kilowatts in the title of the article may be questioned.

Very truly yours,

THOS. SPOONER (A'12, F'29)
(Manager, General Division, Westinghouse Research Laboratories, E. Pittsburgh, Pa.)

To the Editor:

In response to questions concerning my paper "A New Source of 'Kilocycle Kilowatts'" published in the March 1935 issue of ELECTRICAL ENGINEERING, pages 305–7, I submit the following:

Since the preparation and submission of this paper it has become apparent that this method of producing high frequency power has for the present certain limitations that will preclude its immediate successful application in industry except under special conditions.

Arc instability, power losses in choke and stabilizing resistor, and cost of the extremely pure gases necessary are some of the factors that have so far precluded the building of an equipment commercially practical, from an economic standpoint.

The third electrode of the arc tube is an auxiliary electrode to simplify initial starting and has no function in operation.

The optimum gas pressure varies according to tube sizes and electrode spacings. In general, satisfactory results will be found using one atmosphere of hydrogen.

If a magnetic field is used it is coupled transverse to the arc stream. For most frequencies the choke and electromagnetic field may obviously be incorporated in one unit, providing no control of operation is desired by field intensity adjustments.

Operation for very small power outputs and low efficiency may be had below 100 volts direct current. However, stability and efficiency are considerably increased with voltages of 250 to 500 direct current. The input inductance is governed entirely by frequency of operation.

The coil in figure 4, which shows an experimental setup for giving 50 watts of kilocycle frequency power directly from 250 volts direct current, is the choke. No magnetic field is used. Behind the 3 knife switches are 3 condensers of the oscillatory circuit, which may be connected in parallel at will by the switches for frequency change. This small power low voltage equipment gives an over-all efficiency of about 25 per cent, which may be increased to 35 per cent by use of a magnetic field and 50 per cent by use of about 500 volts.

Very truly yours,

L. D. MILES (A'33)
(Vacuum Tube Engg. Dept., General Electric Co., Schenectady, N. Y.)

Internal Price Levels and Foreign Trade

To the Editor:

No nation can long survive and maintain decent living conditions for its people that does not adopt 1 of 2 commercial policies.

It must either establish a price level comparable with that of other nations and trade with them or it may establish any convenient price level and not trade with them, except for those products it has not the facilities to produce.

With free and unrestricted trade among nations all, or nearly all, the manufacturing will naturally and necessarily be done in those countries having the lowest price level.

The original and principal cause of the depression in this country during the past 6 years, is the fact that we have been trying to increase or hold up the price level and manufacturing cost in this country and at

the same time maintain world trade.

These 2 things are not only incompatible but impossible of attainment.

While so-called progressives and new dealers have been frantically demanding that trade barriers between this and other countries be lowered or removed, they have been madly striving to increase or hold up the price level and manufacturing costs in this country far above that of neighboring countries, and while they have been limiting production in this country, they have been demanding that products of other lower price level countries be allowed to come in free into this country.

No more insane or destructive policy could be conceived by mortal man or an incarnate fiend bent on destroying the country and all of its inhabitants in the shortest possible time.

This policy cannot be excused on the plan that it is an experiment for the reason that every sane and intelligent person knows that there can be but one result if this policy is long continued.

Either the United States of America will not long survive as a free and independent nation or it will revert to a second or third class nation with the greater part of the population living in degradation, as many of them are now doing in all the newer additions in all cities and towns in the United States, with the possible exception of Washington, D. C., Muscle Shoals, Boulder Dam, Grand Coulee, Bonneville, and other tax supported government project communities of the country.

Very truly yours,

E. R. Cunningham
(A'96, M'14, and member for life)
(726 S. W. Salmon St., Portland, Ore.)

A Method of Electrical Prospecting

To the Editor:

I have read the article "Methods of Electrical Prospecting" by Donald G. Fink in the March 1935 issue of Electrical Engineering, pages 293–6, with great interest.

In connection with it, your readers may be interested in knowing that an instrument using the "commutated d-c method" described on page 295 of that issue is commercially available.

I have been licensed to build an instrument of this type—the so-called Gish-Rooney apparatus—under patents held by the Carnegie Institution of Washington. The U.S. Geological Survey has been using my instruments very successfully in geological reconnaissance on dam sites.

There is an account of the application of the Gish-Rooney method to prospecting for road gravel, in the February 21, 1935, issue of the *Engineering News-Record*. Some of your readers may be interested in this.

I shall, of course, be glad to have questions concerning electrical prospecting referred to myself.

Very truly yours,

Shelley Krasnow (A'32)
(Instrument Designer, 817 G Street, N. W., Washington, D. C.)

Personal Items

A. E. Kennelly (A'88, M'99, F'13, HM'33, Life Member and past-president) professor emeritus of electrical engineering, Harvard University and Massachusetts Institute of Technology, Cambridge, Mass., has been elected honorary president of the U.S. National Committee of the International Electrotechnical Commission. Doctor Kennelly has been honorary secretary for many years and has served on the committees on rating of electrical machinery and as chairman of the committee on electrical and magnetic magnitudes and units. He served 2 terms as vice president of the Institute, 1892–94 and 1897–98, and was a manager 1894–97 and president 1898–1900. In 1933 he was awarded the Institute's Edison medal for his work in electrical science and engineering. Doctor Kennelly was appointed professor of electrical engineering at Harvard University in 1902, and became professor emeritus in 1930. He has served on the Institute's standards committee almost continuously since 1906 and on the research committee since 1920, as representative on the U.S. National Committee of the International Electrotechnical Commission since 1907, and as a member of the radio advisory committee of the Bureau of Standards since 1925, as well as on a number of others. He recently became chairman of the newly formed sectional committee on electric and magnetic magnitudes and units under the sponsorship of the electrical standards committee of the American Standards Association, which replaces the former special committee of the U.S. National Committee of the International Electrotechnical commission.

J. Allen Johnson (A'07, F'27, and president) chief electrical engineer, Buffalo, Niagara and Eastern Power Corporation, Buffalo, N. Y., has been awarded the 1934 A.I.E.E. national prize for best paper in engineering practice as co-author with R. T. Henry (A'24, M'29, F'33) of the paper "Fundamentals of Design of Electrical Energy Delivery Systems." Mr. Johnson is a native of Massachusetts, and was graduated from Worcester Polytechnic Institute in 1905 with the degree of bachelor of science in electrical engineering. He was then employed by the Ontario Power Company at Niagara Falls, Ont., and was appointed electrical engineer in 1912. This company was purchased by the Hydro-Electric Power Commission of Ontario in 1917, and Mr. Johnson added the duties of assistant engineer. The following year he became chief engineer of the Cliff Electrical Distributing Company and Hydraulic Power Company at Niagara Falls, N. Y., which in a consolidation that year became The Niagara Falls Power Company with Mr. Johnson as electrical engineer. He held this position during the time of rapid development of Niagara power, and since 1929 has been in his present office. A number of papers have been contributed to the Institute by Mr. Johnson, who received honorable mention in the 1933 A.I.E.E. prize awards for best paper in engineering practice. Since 1905, when he was the first chairman of the Worcester Polytechnic Institute Branch, Mr. Johnson has been active in Institute affairs, serving on a number of committees and as a director 1928–32, and a vice president 1932–34. As president he is chairman of the executive committee, and he is also a member of the Edison medal and Charles A. Coffin fellowship and research fund committees, representative on the American Engineering Council assembly, and representative on the John Fritz Medal Board of Awards. A signal honor was recently conferred on Mr. Johnson by Worcester Polytechnic Institute, in the awarding to him of the honorary degree of doctor of engineering on June 14, 1935. In Mr. Johnson's absence, caused by illness, the diploma and doctor's hood were received for him by his son, a member of the graduating class. The citation for Mr. Johnson's degree was, in part: "A leader in the development and application of electrical energy from Niagara Falls, he has for years directed power production at that grand center. From a humble private in the army of electrical engineers . . . . . he has risen to high command, to be an authority in his chosen field . . . . . And this year his fellows in the national American Institute of Electrical Engineers have conferred upon him the highest office within their gift, the presidency of that great organization. . . . ."

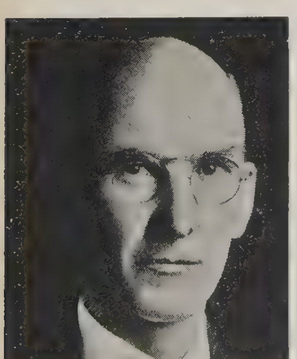
R. T. Henry (A'24, M'29, F'33) electrical engineer in charge of design, Buffalo, Niagara and Eastern Power Corporation, Buffalo, N. Y., with J. Allen Johnson (A'07, F'27, and president) co-author of the paper "Fundamentals of Design of Electrical Energy Delivery Systems," has been awarded the 1933 A.I.E.E. national prize for best paper in engineering practice. Mr. Henry was born at Stronghurst, Ill., and attended schools at Niagara Falls, N. Y., and the General Electric engineering school at Lynn, Mass., where he was engaged as a draftsman in 1908, leaving a year later to join the Niagara Falls Hydraulic Power and Manufacturing Company at Niagara Falls, N. Y. In 1912 he became assistant electrical engineer with the Hooker Electrochemical Company in Niagara Falls, and shortly afterward was employed by the Edison Illuminating Company in Detroit, Mich. In 1914 he returned to Niagara Falls as assistant superintendent of the Niagara Electric Service Corporation, where he was concerned with distribution systems. From 1918 to 1929 he was assistant electrical engineer for The Niagara Falls Power Company, one of a group of companies in the Buffalo, Niagara and Eastern Power Corporation in which he has had his present title since 1929. Mr. Henry served on the Institute's protective devices committee 1931–35, being chairman 1932–34, which automatically made him a member of the technical program committee during those years. During the year 1929–30 he was chairman of the Niagara Frontier Section.

H. A. Affel (A'18, M'23) engineer, Bell Telephone Laboratories, Inc., New York, N. Y., has received honorable mention with co-authors R. W. Chesnut (A'19) and R. H. Mills (A'33) of the paper "Auditory Perspective—Transmission Lines" in the 1934 A.I.E.E. national prize awards for best paper in engineering practice. Mr. Affel graduated from Massachusetts Institute of Technology with the degree of bachelor of science in electrical engineering in 1914, and for 2 years he was research assistant in electrical engineering. From 1916 to 1934 he was employed in the engineering and development and research departments of the American Telephone and Telegraph Company at New York, N. Y., being transferred to the Bell Telephone Laboratories in 1934. His early work was concerned chiefly with investigation of high frequency phenomena on wires and the development of multiplex carrier telephone and telegraph systems. More recently his work has included the broader phases of long distance telephone transmission, repeaters, program circuits, and vacuum tubes, and a number of patents have been issued to him. Mr. Affel has previously presented papers to the Institute, and has addressed several Sections recently on the subject "Precise Frequency and Time Over Wires."

R. W. Chesnut (A'19) carrier telephone engineer, Bell Telephone Laboratories, Inc., New York, N. Y., with his co-authors H. A. Affel (A'18, M'23) and R. H. Mills (A'33) has received honorable mention in the 1934 A.I.E.E. national prize awards for best paper in engineering practice. Mr. Chesnut was born at Kiowa, Kan., in 1892 and was graduated from Harvard University with the degree of bachelor of arts in 1916. He then went to Europe where he spent several years, first as a traveling fellow, from Harvard University, then with the bureau of war inventions of the French Government at Paris engaged on the application of acoustics to war problems, and last as a lieutenant in the U.S. Signal Corps, where he had charge of the research and development of sound ranging of airplanes. Since 1920 Mr. Chesnut has been in the engineering department of the Western Electric Company and its successor, the Bell Telephone Laboratories. Most of his work has been on the development of carrier telephone and long wave radio systems, and a previous Institute paper on carrier telephone cable was prepared by him as a co-author. He is a member of the American Physical Society.

R. H. Mills (A'33) telephone engineer, Bell Telephone Laboratories, Inc., New York, N. Y., shares with his co-authors H. A. Affel (A'18, M'23) and R. W. Chesnut (A'19) honorable mention in the 1934 A.I.E.E. national prize awards for best paper in engineering practice. Mr. Mills, who was first elected an Associate in 1919, was born at Natick, Mass., and graduated from Massachusetts Institute of Technology in 1916 with the degree of bachelor of science. He was employed by the Western Union Telegraph Company as a cable engineer until 1918, when he joined the Western Electric Company in submarine detection work, later engaging in various transmission problems. The Bell Telephone Laboratories were formed in 1924, and since then Mr. Mills has been concerned with the development of selective electrical networks and with apparatus for carrier frequency communication systems.

C. F. Hirshfeld (A'05) chief of research department, Detroit Edison Company, Detroit, Mich., has received the 1934 A.I.E.E. national prize award for best paper in public relations and education for his paper "Engineers of the Next Generation." Doctor Hirshfeld was born at San Francisco, Calif., and studied at the University of California from which he received the degree of bachelor of science in electrical engineering in 1902. Three years later he received his master's degree in mechanical engineering at Cornell University, and in 1932 Rensselaer Polytechnic Institute conferred upon him the honorary degree of doctor of engineering. Between 1903 and 1914 he was successively instructor, assistant professor, and professor of mechanical engineering at Cornell University, at the same time carrying on a consulting practice. He has been chief of the research department of the Detroit Edison Company since 1913 and consulting engineer since 1919, and was chief engineer of the Electric Railway Presidents' Conference Committee of the American Electric Railway Association in 1930. He is the author of numerous papers and articles, including a previous Institute paper, and is a member of a number of societies, among them The American Society of Mechanical Engineers of which he has been a vice president. Doctor Hirshfeld was a member of the Institute's power generation committee 1922–31, of the standards committee 1923–30, and of the electrical machinery committee 1926–27, and has been chairman of Engineer's Council for Professional Development since its inception.



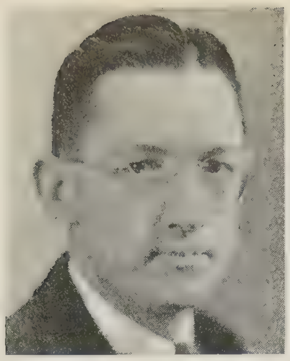
J. ALLEN JOHNSON

R. T. HENRY

C. F. HIRSHFELD

C. L. Dawes (A'12, M'15) associate professor of electrical engineering, Harvard University, Cambridge, Mass., has received honorable mention in the 1934 A.I.E.E. national prize awards for best paper in public relations and education for his paper "Encouraging Initiative in the Engineering Student." Professor Dawes last year received the 1933 A.I.E.E. North Eastern District prize for best paper. He was born at Somerville, Mass., and in 1909 received the degree of bachelor of science in electrical engineering at Massachusetts Institute of Technology, where he was an assistant until 1911. He then went to Harvard University as an instructor. For a time he was absent on leave to be professor of electrical engineering at the United States Naval Academy, and was an instructor at the Naval Aviation Ground School at Massachusetts Institute of Technology when it was combined with Harvard University from 1915 to 1919. From 1919 to 1931 he was assistant professor of electrical engineering at Harvard University, and for some years has been engaged in consulting work for a number of electrical industries. Several papers on engineering and educational subjects have been written by him.

F. W. Smith (A'05, M'12) president, New York Edison Company, and United Electric Light and Power Company, New York, N. Y., has been elected president of the Consolidated Gas Company of New York to succeed G. B. Cortelyou, who is retiring. Mr. Smith has had a long career in the electrical industry, having first entered it in 1880 when he was employed by the United States Illuminating Company, which subsequently became a part of the United Electric Light and Power Company. He was elected secretary of the latter in 1905, vice president in 1912, and was appointed general manager in 1916. This company was originally formed for the purpose of developing the a-c system, so that Mr. Smith has been actively identified with this development. In 1926 he was elected chairman of the board of directors of the New York and Queens Electric Light and Power Company, and in 1929 was elected president of the Brush Electric Illuminating Company. He was elected vice president of the New York Edison Company in 1931, and the following year became president of this company and of the United Electric Light and Power Company. In addition, he has served as director of a number of other companies. Mr. Smith is a member of the board of trustees of the Edison Electric Institute, a past-president of the National Electric Light Association, and a member of the Electrical Association of New York, New York Electrical Society, and other technical organizations



J. R. MEADOR

H. S. BLACK

H. S. Black (A'23, M'33) member of the technical staff, Bell Telephone Laboratories, Inc., New York, N. Y., has received the award for best paper in theory and research in the 1934 A.I.E.E. national prizes, for his paper, "Stabilized Feedback Amplifiers." Mr. Black was born at Leominster, Mass., in 1898 and received the degree of bachelor of science in electrical engineering at Worcester Polytechnic Institute. He joined the engineering department of the Western Electric Company at New York in 1921. This department later became the Laboratories. Mr. Black has participated in the development of many aspects of carrier telephone systems, including repeaters and line filters, and is the inventor of the amplifier described in his paper. In recent years he has had charge of a group devoted primarily to carrier repeater development. Mr. Black has written other technical papers, and is a co-author of a previous Institute paper on a carrier telephone system for short toll circuits.

J. R. Meador (A'34) electrical engineer, General Electric Company, Pittsfield, Mass., has been awarded the 1934 A.I.E.E. national prize for initial paper, his contribution being "Calibration of the Sphere Gap." Mr. Meador was born at Dallas, Texas, in 1905 and received the degree of bachelor of science in electrical engineering at Texas Agricultural and Mechanical College in 1927, obtaining his master's degree the following year. He then entered the testing department of the General Electric Company, and in 1930 transferred to the power transformer department, where he spent 2 years in the high voltage engineering laboratory. He is engaged at present in research and development relating to the cooling and insulation of transformers.

I. E. Moultrop (A'10, M'12, F'29) chief engineer and superintendent of construction bureau, Edison Electric Illuminating Company of Boston, Mass., has been elected a trustee of Northeastern University, Boston, and was appointed a member of the visiting committee by President Speare of the university. Mr. Moultrop has been a member of the Institute's power generation (formerly power stations) committee since 1916, and has served on the automatic stations committee since 1930. He has also been active on several other committees in recent years.

H. S. Hamilton (M'24) telephone engineer, Bell Telephone Laboratories, Inc., New York, N. Y., has received honorable mention in the 1934 A.I.E.E. national prize awards for initial paper, for his paper "Wide-Band Open-Wire Program System." Mr. Hamilton was born at Marblehead, Mass., in 1893 and received the degree of bachelor of science in electrical engineering at Tufts College. From 1916 to 1934 he was employed by the American Telephone and Telegraph Company in transmission development work, and since 1934 has been in the transmission development department of the Laboratories. He was first engaged particularly in repeater development, and during 1918 directed a field group in a campaign to improve the service between New York and Washington, D. C. Following this Mr. Hamilton directed the unloading of transcontinental circuits and equipping them with new repeaters. Since 1923 he has been closely associated with the development of circuits for radio program transmission, among the more recent projects being the wide band program system for open wire lines inaugurated in 1931 and the special 15 kilocycle circuits between Philadelphia, Pa., and Washington in 1933 for the demonstration of auditory perspective, on which he prepared an article for the *Bell Telephone Quarterly*. Recently Mr. Hamilton has been engaged in development of carrier telephone systems for open wire circuits.

J. V. Lamson (A'29) instructor in the college of engineering, University of Washington, Seattle, has received honorable mention in the 1934 A.I.E.E. national prize awards for initial paper, for his paper "Trolley Wire Lubrication Improved." He was born in Illinois in 1902, and after graduation from the University of Washington in 1926 worked in the test department of the General Electric Company for almost 2 years, applying a considerable portion of the time in the electric railway and heavy machinery fields. For the following 2 years he was an assistant engineer in the electrification department of the Chicago, Milwaukee, St. Paul and Pacific Railroad at Seattle, Wash., where he became interested in contact line and current collection problems. In 1930 he became an instructor in the department of general engineering at the University of Washington. Facilities in the laboratory made possible the study of current collection in heavy traction systems which led to the preparation of his paper. Mr. Lamson is at present, during the summer, making a study of current collecting devices for the Ohio Brass Company.

H. S. Vassar (A'06, M'18) laboratory engineer, Public Service Electric and Gas Company, Irvington, N. J., has been nominated for president of the American Society for Testing Materials. Mr. Vassar, a graduate of Pratt Institute, Brooklyn, N. Y., has been in charge of electrical, mechanical, and chemical testing for the company since 1911, having previously been with the United Electric Company and the Public Service Railway Company, both in Newark, N. J. He was a member of the Institute's electrophysics committee 1920–21, and of the instruments and measurements committee in 1920 and 1922–25. For the past year he has been vice president of the American Society for Testing Materials, of which he has been a member since 1915, and is active in the work of the committee on electrical insulating materials, serving as its chairman 1926–30.

W. B. Sanford (A'04, M'30) plant manager, Bell Telephone Laboratories, Inc., retired from the laboratories on May 1, 1935, after more than 31 years of active service. In 1901 Mr. Sanford entered the factory engineering department of the Western Electric Company upon the completion of the mechanical engineering course at Cornell University. Although he left the department 2 years later, he returned in 1905 and in 1909 was appointed factory engineer, in charge of plant operation and construction. In 1913 he was given supervision of the shop departments, and was transferred to the general purchasing department in 1915. During the war period he superintended the manufacture of vacuum tubes for government use, and since then has superintended practically all physical alterations in the laboratories' building.

A. N. Goldsmith (M'15, F'20, and Life Member) consulting engineer, New York, N. Y., has had the honorary degree of doctor of science conferred upon him by Lawrence College at Appleton, Wis. The citation made by President Wriston of the college stated that the degree was in part conferred "in recognition of the unique place which Doctor Goldsmith has made in his chosen field." Doctor Goldsmith is a past-president of the Institute of Radio Engineers and of the Society of Motion Picture Engineers and is a member of numerous engineering and scientific societies.

H. E. Ives (F'29) director, electro-optical research, Bell Telephone Laboratories, Inc., New York, N. Y., has been appointed a fellow for research in color science at the Fogg Art Museum of Harvard University, Cambridge, Mass. Doctor Ives was formerly in charge of experimental work in airplane photography for the aviation section of the U.S. Signal Corps, and is the holder of the John Scott medal for pioneer work in electrical telephotography and television. He served on the Institute's committee on production and application of light 1932–34.

J. E. ALLEN (A'21) chief of tests, Pennsylvania Water and Power Company, Baltimore, Md., with his co-author G. J. Gross (A'30) has been awarded a James H. McGraw prize by the Edison Electric Institute for one of the 3 most meritorious papers on any engineering or technical subject relating to the electric light and power industry during the year. Mr. Allen was a member of the A.I.E.E. protective devices committee 1929–31.

G. J. GROSS (A'30) test engineer, Pennsylvania Water and Power Company, Baltimore, Md., shares with his co-author J. E. Allen (A'21) a James H. McGraw prize awarded by the Edison Electric Institute for one of the 3 most meritorious papers on any engineering or technical subject relating to the electric light and power industry during the year.

M. L. WARING (A'29) system engineering department, New York Edison Company, New York, N. Y., has been awarded a James H. McGraw prize by the Edison Electric Institute as author of one of the 3 most meritorious papers on any engineering or technical subject relating to the electric light and power industry during the year.

Obituary

ORVILLE HIRAM ENSIGN (A'04, M'05, F'13, and member for life) one of the Los Angeles Section's most prominent members, died at his home in Pasadena, Calif., June 1, 1935. Mr. Ensign was born at Ithaca, N. Y., July 8, 1863. After completing 2 years of work in the course of "mechanical arts" with the class of 1884 at Cornell University he was, until 1893, variously employed by the Edison United Electric Company of New York City on construction work, and by the General Electric Company, Schenectady, N. Y., successively as machinist, draftsman, in charge of railway motor test work, and finally for $2^1/_2$ years as chief inspector for the factory. In 1893 Mr. Ensign moved to California as consulting engineer for the Redlands Electric Light and Power Company in connection with the completion and the placing in service of the "first 3 phase power transmission plant in the United States," the historic Mill Creek plant near Redlands, Calif. During 1894–95 Mr. Ensign was electrician and superintendent of motive power for the Pasadena and Los Angeles Electric Railway and the Los Angeles and Santa Monica Electric Railway, constructing and operating the former and partially constructing the latter. From 1896 to 1904, Mr. Ensign served as electrical and mechanical engineer for the Redlands Electric Light and Power Company and its successors, the Southern California Power Company and the Edison Electric Company (now the Southern California Edison Company, Limited). Mr. Ensign had entire charge of the design and construction of the plants built by these 3 companies, and in 1896 undertook the development of an 83-mile 33,000-volt transmission line from Santa Ana Canyon near Redlands to Los Angeles, the first "long distance" high voltage polyphase line. In 1904 Mr. Ensign became chief electrical engineer for the U.S. Reclamation Service, which position he held until 1915 when he retired to assume private practice as a consulting engineer in Los Angeles. Also at that time Mr. Ensign founded the Ensign Carburetor Company of which at the time of his death he was president and chief engineer. He retired from general consulting practice in 1927. One of the most notable services rendered by Mr. Ensign was his membership on the board of consulting engineers for the bureau of power and light of the City of Los Angeles, which was actively used during the formative and construction period of the bureau's hydroelectric and distributing systems from 1910 to 1921.

EDWARD ALLEN COLBY (A'89, M'89, and member for life) consulting engineer and secretary, Baker and Company, Inc., Newark, N. J., died June 2, 1935. He was born at St. Johnsburg, Vt., August 1, 1857, and entered the Sheffield Scientific School of Yale University in 1877, receiving the degree of bachelor of philosophy in 1880. For a short time he taught natural science, and in 1881 was employed by the United States Electric Lighting Company at New York, N. Y., installing the first incandescent lighting on Hudson River ferryboats. The following year he became assistant to Edward Weston (A'84, M'84, HM'33, past-president, and member for life) having charge of the lighting department in the laboratory at Newark, N. J. In 1887 Mr. Colby invented an induction electric furnace for the melting of metals, which is the basis of the present electric steel melting industry. In recognition of this invention he was awarded a medal and diploma by the Franklin Institute. A process for the melting of platinum was perfected by him in 1893. Mr. Colby had left Newark in 1887, but returned to the Weston Electrical Instrument Company in 1889. About 1900 he became chief engineer and superintendent of the Baker Platinum Works in that city, retiring from this position in 1930, although he continued as consulting engineer and secretary until his death. Mr. Colby was also a member of the American Chemical Society, Society of Chemical Industry, and American Electrochemical Society.

LAWRENCE DORSY BALE (A'10, M'26) superintendent of power, Cleveland Railway Company, Cleveland, Ohio, died May 16, 1935. He was born at Louisville, Ky., January 22, 1882, and studied electrical engineering at Rose Polytechnic Institute. He was employed by the Western Union Telegraph Company in 1899 at Louisville, and in 1901 went to St. Louis, Mo., where he was employed by the United Railways Company. In 1908 he was employed in Cleveland, Ohio, by the Municipal Traction Company, later the Cleveland Railway Company. While superintendent of substations for this company Mr. Bale made an extensive study of automatic substations, and in 1919 the first automatic substations for metropolitan service were installed. In 1923 the first comprehensive remote supervisory control system was designed and installed in connection with these substations. Mr. Bale was appointed superintendent of power in 1925. He was the author of an Institute paper on automatic substations and at the time of his death was a member of the automatic stations committee of the Institute, on which he had served since 1928. During 1922–23 he was chairman of the Cleveland Section, and since then had served on the Section's advisory board. Mr. Bale was also a member and past-president of the American Transit Engineering Association, now the American Transit Association.

TALBOT GRANT MARTIN (F'32) president, Associated Electric Laboratories, Inc., Chicago, Ill., died April 10, 1935. He was born in Cumberland County, Pa., October 6, 1865, and in 1889 entered telephone work with the Chicago Telephone Company. In 1893 he became connected with the Strowger Automatic Telephone Exchange, a manufacturing company, and from 1901 to 1931 was with the Automatic Electric Company and Automatic Electric Incorporated. In 1931 he became vice president and director of development and research of Associated Electric Laboratories, Inc., and subsequently president. Mr. Martin had been actively engaged in the design of Strowger automatic telephone systems since 1893, and was recognized as a leading authority in this work. In the period from 1904 to 1926 there were issued to him 105 United States patents covering telephone systems and apparatus, representing many important practical advancements. The success of the Strowger automatic system, which is widely used in the United States and foreign countries, is credited largely to his inventive genius. Among his developments were arrangements for trunking between manual and automatic exchanges and a system for transmitting music over subscribers' lines which would be cut off by a telephone call.

CHARLES FREDERICK LACOMBE (A'06, M'09, F'13) consulting engineer, Babylon, N. Y., died May 26, 1935, one day before his seventieth birthday. He was associated with W. S. Leffler (A'24) in a consulting practice with headquarters in New York, N. Y. Mr. Lacombe was born at New York May 27, 1865, and graduated from the Columbia University School of Mines in 1885. After several years of mining work in western states he was engaged in enlarging and operating an electric light plant in Colorado, and at this time, in 1890, formed the Mountain Electric Company, for which he acted as president, general manager, and electrical engineer. The company erected a number of electric power plants in Colorado, New Mexico, and Utah, and with the development of long distance transmission about 1895 built some of the first long lines. In 1901 a plant he designed for street lighting in Denver, Colo., was completed, and shortly afterward Mr. Lacombe went to New York, where he took charge of the lighting bureau of the city in January 1903. Other

duties subsequently added led to the title of chief engineer of light and power, with charge of the lighting and electrical inspection in the 5 boroughs of the city. In 1915 Mr. Lacombe became a consultant in rate cases and street lighting, but 2 years later entered military service. In 1918 he was assigned to the power section of the War Industries Board at Washington, D. C., and was executive assistant to the power director of the United States. Two years later he wrote the report of the National Electric Light Association on national power resources, and in 1921 became director of economics and statistics for the Brooklyn Edison Company, Brooklyn, N. Y. After 6 years in this position he again engaged in consulting practice at New York. Mr. Lacombe was also a member of The American Society of Mechanical Engineers, Illuminating Engineering Society and other technical organizations.

Charles Newbold Black (A'90 and member for life) vice president, Ford, Bacon and Davis, Inc., San Francisco, Calif., died May 15, 1935. He was born at New York, N. Y., March 16, 1867, and attended Princeton University, from which he received the degrees of bachelor of arts and electrical engineer in 1888 and 1890, respectively. Mr. Black was general superintendent of the Brush Electric Company, Cleveland, Ohio, until he became connected with Ford, Bacon and Davis at New York in 1899 as an engineer, and in 1905 became vice president and general manager of the Kansas City Railway and Light Company. Two years later he undertook similar duties with the United Railroad of San Francisco, becoming president of its successor, the Market Street Railway, from 1922 to 1925. During 1916–18 Mr. Black was head of the export department of J. P. Morgan and Company, negotiating contracts for war supplies, and later was a colonel of ordnance on the staff of General Pershing. He had been a trustee of Princeton University, and was a member of the University, Engineers, and Princeton clubs of New York, and the Pacific Union, Bohemian, and University clubs of San Francisco.

Basil Lanphier (A'18, M'22) American Gas and Electric Company, New York, N. Y., died in April 1935. He was born at Lohrville, Iowa, and received the degree of bachelor of arts at Creighton University, Omaha, Neb., in 1912. The following year he entered Massachusetts Institute of Technology, where he received the degree of bachelor of science in electrical engineering in 1916. He was then engaged in maintenance work for the Bethlehem Steel Company, Lebanon, Pa., until 1918, becoming assistant to the chief engineer. In that year he accepted the position of assistant engineer with the Interborough Rapid Transit Company, New York, N. Y., and 2 years later was appointed electrical research engineer in charge of power station and substation tests and purchase of various equipment. Since 1923 he had been connected with the American Gas and Electric Company. Mr. Lanphier was a co-author of a 1932 Institute paper on automatic equipment on the American Gas and Electric system.

Eli Judson Blake (A'04) partner, Blake and Van Nieukerken, Philadelphia, Pa., died May 17, 1935. He was born at Newark, N. J., June 2, 1879, and received the degree of bachelor of arts from Princeton University in 1901, after which he was employed in the apprentice courses of the Westinghouse Electric and Manufacturing Company and the General Electric Company. In 1904 he entered the electric department of the New York Central Railroad at New York, N. Y., being assistant engineer in 1913 when he accepted a position as electrical engineer with the Hall Switch and Signal Company, Garwood, N. J. He became electrical engineer for the Gould Coupler Company, Depew, N. Y., engaging in the development of apparatus for train lighting, in 1917, and in 1926 continued this work with the Gould Car Lighting Company, Rochester, N. Y. Two years later he became car lighting engineer for the American Brown Boveri Electric Company at Camden, N. J., and a year later was appointed general engineer. Since 1930 he had been engaged in consulting engineering.

Frederick Louis Pierce (A'10) director, Cutler-Hammer, Inc., Milwaukee, Wis., died April 16, 1935. He was born at Milwaukee July 8, 1860, and after several years manufacturing experience became treasurer of The Cutler-Hammer Manufacturing Company in 1897, retaining this position until 1929. From 1903 to 1909 he was also treasurer of the Bliss Electric Car Lighting Company, Milwaukee, and for several years was treasurer of the National Battery Company, Buffalo, N. Y. In addition to his directorship of Cutler-Hammer, Inc., Mr. Pierce was a director of the Marine National Exchange Bank, Schweitzer and Conrad, Inc., and Columbia Hospital, and a trustee and member of the finance and executive committees of the Northwestern Mutual Life Insurance Company.

J. Logan MacBurney (A'15) sales engineer, the Electric Storage Battery Company, Philadelphia, Pa., died May 26, 1935, 2 weeks after his election as chairman of the Philadelphia Section for the coming year. Mr. MacBurney was born at Philadelphia April 7, 1890, and graduated from the electrical engineering department of the University of Pennsylvania in 1911, when he entered the construction department of the Electric Storage Battery Company. In 1915 he was transferred to the engineering department, and since 1922 he had been sales engineer. For the past 6 years Mr. MacBurney had been secretary of the Institute's Philadelphia Section, and on August 1, 1935, he would have assumed the office of chairman.

James Simcoe Fitzmaurice (A'93, M'94, and member for life) consulting electrical and mechanical engineer, Adelaide, South Australia, died in April 1935. He was born at Victoria in 1861, and was for many years assistant electrical engineer in the Postmaster Generals Department at Sydney, having previously been chief engineer in the light branch at Balmain, New South Wales. In 1912 Mr. Fitzmaurice became electrical engineer in the Postmaster Generals Department at Perth, West Australia, and in 1919 was appointed state engineer at Adelaide, South Australia. Since 1928 he had been engaged in consulting engineering. For many years Mr. Fitzmaurice was a local honorary secretary of the Institute. He was also a member of the Institution of Electrical Engineers of Great Britain.

Arthur Jean Townsend (A'10) executive vice president, Rotary Electric Steel Company, Detroit, Mich., died June 1, 1935. He was born at Apollo, Pa., October 5, 1887, and in 1909, after study at Ohio University, became connected with the Canadian Sheet Steel Corporation, Morrisburg, Ont., Can. Two years later he was employed by the Portsmouth Steel Company, Portsmouth, Ohio, until he became electrical engineer for the Berger Manufacturing Company, Canton, in 1914. In 1917 he became vice president and works manager of the National Pressed Steel Company, Massillon, and in 1922 vice president of The Columbia Steel Company, Elyria. For several years following 1927 he was a consulting engineer at Canton.

Norman James Wilson (A'02) electrical engineer, J. G. White and Company, London, England, died July 31, 1934, according to word just received at Institute headquarters. He was born at Stockport, England, November 5, 1873, and received his technical education at Bristol and London. In 1900 he became connected with the British Westinghouse Electric and Manufacturing Company, and for a time studied American methods and practices at the East Pittsburgh, Pa., plant of the Westinghouse Electric and Manufacturing Company. He later engaged in consulting engineering in Liverpool until assuming the position of electrical engineer with J. G. White and Company in 1913.

John G. Kleindienst (A'30) sales engineer, Delano Coal Company, New York, N. Y., died recently. He was born at Mahanoy City, Pa., October 10, 1900, and received the degree of bachelor of science in electrical engineering at Drexel Institute in 1928, having previously been employed for short periods of time by the General Electric Company at Philadelphia, Pa., and by the Pennsylvania Power and Light Company. Prior to his position with the Delano Coal Company he had been employed by the Brooklyn Edison Company, Brooklyn, N. Y.

James Francis Greene (A'27) Los Angeles, Calif., died in February 1935. He was born at Blackstone, Mass., August 18, 1899, and received the degree of bachelor of science in the electrical engineering course at Rhode Island State College in 1922. He then entered the employ of the Victor Talking Machine Company, being located at Camden, N. J., and Buenos Aires, Argentina, until he went to Culver City, Calif., in 1929 as recording supervisor at Hal Roach Studios, Inc.

Membership

Recommended for Transfer

The board of examiners, at its meeting of June 19, 1935, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Member

Brouwers, Peter W., div. plant engr., New England Tel. & Tel. Co., Providence, R. I.
Burris, Harry L., master mechanic, Great Western Electro-Chemical Co., Pittsburg, Calif.
Card, Read H., engr., American Tel. & Tel. Co., New York, N. Y.
Champe, Willard, editorial dept., A.I.E.E., New York, N. Y.
Ellerman, Louis H., asst. supt., testing labs., City of Los Angeles, Bureau of Power & Light, Los Angeles, Calif.
Fetzer, John E., pres., WKZO, Inc., Kalamazoo, Mich.
Fort, Tomlinson, central sta. repr., Westinghouse Elec. & Mfg. Co., New York, N. Y.
Hartung, Arthur F., assoc. engr., Burns & McDowell Engg. Co., Kansas City, Mo.
Howard, Alan, engr., General Electric Co., Schenectady, N. Y.
Morgan, Alva B., rate and pwr. consultant, Edison Electric Institute, New York, N. Y.
Mueller, George V., asst. prof. of elec. engg., Purdue University, W. Lafayette, Ind.
Murray, John M., elec. engr., Simplex Wire & Cable Co., Cambridge, Mass.
Purnell, Clayton S., transportation repr., Westinghouse Elec. & Mfg. Co., New York.
Ransom, Glen B., engg. employee, American Tel. & Tel. Co., New York, N. Y.
Rivers, Fabian N., technical employee, American Tel. & Tel. Co., New York, N. Y.
Schlossberg, Victor E., asst. supt. elec. & pwr. depts., Inland Steel Co., E. Chicago, Ind.
Sterba, Ernest J., member, technical staff, Bell Telephone Labs. Inc., Deal. N. J.
Taylor, Frank W., high voltage engr., Hollinwood, England.
Tripp, William A., engr., Jackson & Moreland, 31 St. James Ave., Boston, Mass.

19 to Grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before July 31, 1935, or Sept. 30, 1935, if the applicant resides outside of the United States or Canada.

Ackley, O. B., S. S. White Dental Mfg. Co., Princess Bay, Staten Island, N. Y.
Ahlquist, R. W., Univ. of Pittsburgh, Pittsburgh, Pa.
Alexander, E. L., 504 West 135th St., New York, N. Y.
Atwood, P. W., R. F. D. No. 2, Windsor, Vt.
Baily, G. O. (Member) American Tel. & Tel. Co., New York, N. Y.
Baines, L. E., Central Stamping Co., Newark, N. J.
Baumzweiger, B., Univ. of Cincinnati, Cincinnati, Ohio.
Bergdahl, M. A., Okonite Co., Detroit, Mich.
Berger, W. R., United Elec. Lt. & Pwr. Co., New York, N. Y.
Boyd, S. F. Jr., Black Point Inn, Prout's Neck, Me.
Brown, C. E., Driggs Ordnance and Engg. Co., New York, N. Y.
Callahan, J. L. (Member), R. C. A. Communications, Inc., New York, N. Y.
Carroll, S. O., Union Gas & Elec. Co., Cincinnati, Ohio.
Clarke, T. C., Northern Elec., Vancouver, B. C., Can.
Cole, O. I., American Tel. & Tel. Co., Cleveland, Ohio.
Cotman, C. A., Chain Products Co., Cleveland, Ohio.
de Villa, F., c/o M. del Corral & Co., New York, N. Y.
Dalton, J. P., 51 W. 170th St., New York, N. Y.
Downing, W. C. Jr. (Member), Lincoln Meter Co., Springfield, Ill.
Duffy, G. E. Sr., General Railway Signal Co., Rochester, N. Y.
Farnum, P. T. (Member), American Tel. & Tel. Co., New York, N. Y.
Faust, C. A., Transit Journal, New York, N. Y.
Fifer, W. H., Naval Research Lab., Bellevue, D. C.
Gallagher, J. J., Standard Shipping Co., New York, N. Y.
Goldenberg, F., Pennsylvania Water & Power Co., Baltimore, Md.
Haglund, C. E., Pacific Gas & Elec. Co., San Francisco, Calif.
Helwith, E. E., 66 Worth St., New York, N. Y.
Hermanson, E. W., U.S. Naval Academy, Annapolis, Md.
Hertzler, E. A., Pratt Inst., Brooklyn, N. Y.
Holmes, W. M. (Member) Ventura Junior Coll., Ventura, Calif.
Jones, F. C., c/o B. F. Sturtevant Co., Hyde Park, Mass.
Kemerer, M. P., Southern Calif. Edison Co. Ltd., Alhambra.
Knoderer, C. L., American Tel. & Tel. Co., New York, N. Y.
Lane, C. A., 14 E. 80th St., New York, N. Y.
Lannert, K. E., Carter Carburetor Corp., St. Louis, Mo.
Liddy, C. E., All America Cables Inc., Cristobal, Canal Zone.
Malloy, C. T., 8019 So. Mariposa Ave., Los Angeles, Calif.
McDermott, J. A., Barr, Irons & Lane, New York, N. Y.
Miller, C. R., Village Hall, Winnetka, Ill.
Moore, R. K. Jr., Scranton Elec. Co., Scranton, Pa.
Murphy, J. J., 191 E. 31st St., Brooklyn, N. Y.
Newman, W. L. (Member), American Tel. & Tel. Co., New York, N. Y.
Organic, W. V., Carnegie Steel Co., Youngstown, O.
Plautz, A. C., 10358 Rossbury Place, Los Angeles, Calif.
Ponsolle, W. J., 73 W. 88th St., New York, N. Y.
Ring, J. P., Abbott Machine Co., Wilton, N. H.
Rizk, K. S., U.S. Coast & Geodetic Survey, Jacksonville, Fla.
Rutherford, E. J. (Member), American Tel. & Tel. Co., New York, N. Y.
Sayres, D. B. Jr., Wirt Co., Philadelphia, Pa.
Santacruz y Carral, C., General Elec. S. A., Mexico, D. F., Mexico.
Short, B. H., Purdue University, West Lafayette, Ind.
Silver, H. S., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Stanwix-Hay, W. H., General Electric Co., Bridgeport, Conn.
Westcott, D. B., 7 East St., Northfield, Vt.
Whistler, J. K., 2612 N. E. 23rd, Oklahoma City, Okla.
Willson, A. R. (Member), Dept. of Public Wks., Olympia, Wash.
Woolley, H. W., Freshman Coll., Sandusky, Mich.
Yamashita, H., Hotel Kokumai, New York, N. Y.

58 Domestic

Foreign

L. E, Metz, .G.Messrs. Metropolitan Vickers Elec. Co. Ltd., Manchester, Eng.
Shivapuri, P. R. N., Punjab Elec. Pwr. Co., Ltd., Gujrat, Lahore, India.

2 Foreign

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, with the address as it now appears on the Institute record. Any member knowing of corrections to these addresses will kindly communicate them at once to the office of the secretary at 33 West 39th St., New York, N. Y.

Bauer, Charles, 9 Royalton Place, Bloomfield, N. J.
Bock, F. S., 1642 W. Broad St., Richmond, Va.
Chiofalo, J., 203 Graham Ave., Brooklyn, N. Y.
Germenshausen, K. J., M.I.T., Dorm., Cambridge, Mass.
Golikoff, A., Main P. O. Gen. Del., Moscow, U.S.S.R.
Greene, F. M., 656—50th St., Brooklyn, N. Y.
Haddad, Raphael A., 500 Riverside Drive, N. Y. City.
Houston, Chas. E., 400—10th Ave., S. E., Minneapolis, Minn.
Kimball, Gordon S., 154 Elmer Ave., Schenectady, N. Y.
Martinoff, V. M., 2150 Queen St., Toronto, Ont., Can.
Nelson, Charles J., 1515 N. Lotus Ave., Chicago, Ill.
Rasmussen, David, 423 Hickory St., Ridgway, Pa.
Roman, Walter G., 511 Pitt St., Wilkinsburg, Pa.
Rozelle, P. M., 2018 Chestnut St., Harrisburg, Pa.
Schellberg, Kenneth O., 4115—51st St. S., Seattle, Wash.
Schlosser, Walter H., Dominion Elec. Power, Ltd., Regina, Sask., Can.
Smedley, A. B., 82 Warner Ave., Hempstead, N. Y.
Thomson, W. L., 3630 Spruce St., Philadelphia, Pa.
Verrier, E. J., Anglo Newfoundland Dev. Co., Grand Falls, Newfoundland.
Watson, J. Connell, 69 Cambridge Terrace, London, W. 2, Eng.

20 Addresses Wanted

Engineering Literature

Among the new books received at the Engineering Societies Library, New York, recently, are the following which have been selected because of their possible interest to the electrical engineer. Unless otherwise specified, books listed have been presented gratis by the publishers. The Institute assumes no responsibility for statements made in the following outlines, information for which is taken from the preface of the book in question.

HOT WATER and STEAM SUPPLY by ELECTRICITY. By F. C. Smith. Lond., E. & F. N. Spon, Ltd.; N. Y., Engineers Book Shop, 1934. 142 p., illus., 9x6 in., cloth, $3.50. An explanation of the thermal and electrical fundamentals, with description of various types of apparatus and their installation.

Introduction to ELECTRIC TRANSIENTS. By E. B. Kurtz and G. F. Corcoran. N. Y., John Wiley & Sons, 1935. 335 p., illus., cloth, $4.50. A text for class use giving an account of transient disturbances in both a-c and d-c circuits of varying degrees of complexity.

MARKETING INDUSTRIAL EQUIPMENT. By B. Lester. N. Y. and Lond., McGraw-Hill Book Co., 1935. 307 p., illus., 9x6 in., cloth, $3.50. An outline for a study of the distribution of capital goods of an engineering nature from the manufacturer to the ultimate user, discussing market and product analysis, economic distribution principles, and organization and operation of sales departments and sales outlets.

MECHANIZATION in INDUSTRY. By H. Jerome. N. Y., National Bureau of Economic Research, 1934. 484 p., illus., 9x6 in., cloth, $3.50. The nature and the results of progressive mechanization, and its social and economic consequences, are discussed at length, and much detail as to actual changes is presented.

PRACTICAL SOLUTION of TORSIONAL VIBRATION PROBLEMS. By W. K. Wilson. N. Y., John Wiley & Sons, 1935. 438 p., illus., 9x6 in., cloth, $7.00. The principles and computation details of torsional vibration in a manner suitable for everyday reference, with illustrative examples.

PROCEEDINGS of the FOURTH INTERNATIONAL CONGRESS for APPLIED MECHANICS, Cambridge, Eng., July 3–9th, 1934. Univ. Press, Cambridge, 1935. 283 p., illus., 11x7 in., cloth, £1. The 7 general lectures delivered at the congress including recent progress in analyzing machines, and vibration and turbulence problems.

PUBLIC UTILITY VALUATION for PURPOSES of RATE CONTROL. By J. Bauer and N. Gold. N. Y., Macmillan Co., 1934. 477 p., 9x6 in., cloth, $3.50. A comprehensive discussion of utility valuation, including economic and legal fundamentals, practical methods pursued, procedural aspects of valuation, and present system of rate regulation.

TABLES and OTHER DATA for ENGINEERS and BUSINESS MEN, compiled by members of the college of engineering of the University of Tennessee. Knoxville, U. of T. Co-operative Book Store. 139 p., tables, 6x3 in., lea., $.75. A convenient selection of mathematical, mechanical, and electrical tables and formulas which are constantly used by engineers.

THEORY of ALTERNATING CURRENT WAVE FORMS. By P. Kemp. Pittsburgh, Instruments Pub. Co., 1935. 218 p., illus., 9x6 in., cloth, $4.50. A discussion of nonsinusoidal waves, presenting the facts necessary for proper understanding, with short bibliographies to guide further study.

VDI JAHRBUCH, Die Chronik der Technik Berlin, VDI-Verlag, 1935. 183 p., 8x6 in., paper, 3.50 rm. A series of concise reports upon scientific and technical developments during 1934, with references to the original publications.

THOMAS' REGISTER of AMERICAN MANUFACTURERS. 25 ed. 1935, the Largest Classified Reference Book in the World. N. Y., Thomas Pub. Co., 1935. 10,914 columns, illus., 12 x 9 in., cloth, $15.00 (to advertisers and renewal subscriptions $10.00). A directory of manufacturers, manufactured products with the names of the makers, and trade names, with the addition of banks, commercial institutions, and trade papers.

Industrial Notes

Large Orders for Westinghouse.—The Westinghouse Elec. & Mfg. Co. has received an order totaling $299,000 from the J. G. Brill Co., of Philadelphia, for the Delaware River Bridge Joint Commission. The electrical equipment consists of four 100 hp motors and automatic electropneumatic battery control, and also includes the panels, fans, and other electrical accessories.

Another order, amounting to $100,000, covers the motor and control equipment for a new 42 inch reversible cold strip mill of the Republic Steel Co., at Warren, O., and includes a 1200 hp mill motor and two 300 hp reel motors.

American Sheet Promotions.—According to a recent announcement, O. E. Romig, former metallurgist, Gary sheet mill, has been appointed manager of the electrical sheet division of the American Sheet & Tin Plate Co., Frick Bldg., Pittsburgh. James B. Barton has been appointed sales engineer of the electrical sheet division, at Pittsburgh. He was formerly associated in a similar capacity with the Empire Sheet and Tin Plate Co., Mansfield, O.

Rockbestos Promotes Redfield.—Kendall A. Redfield, advertising manager of the Rockbestos Products Corp., New Haven, Conn., manufacturers of asbestos insulated electrical wires and cables, has been made assistant general sales manager. Herbert O. Anderson is general sales manager.

Owens-Illinois Glass Promotions.—Stanley J. McGiveran has been appointed to the position of manager of sales merchandising. W. M. Gates has been advanced to the position of assistant to the general sales manager. T. K. Almorth, as advertising manager, will continue to direct the advertising of the various divisions, together with glass block, Hemingray insulators, and industrial materials.

Smaller O-B Universal Strain Clamp.—The Ohio Brass Co., Mansfield, O., announces that it has extended the economy of its universal strain clamp by introducing the baby universal clamp. In principle of design this new strain clamp is exactly like the larger O-B universal. The primary snub, in combination with a modified "V" wire groove and a positive clamping member, makes this smaller clamp applicable to the range of conductor sizes and types used on rural electrification. It will take No. 6 to No. 2 solid or stranded cables. The only difference in the two universal strain clamps are size and cost.

Automatic Synchronous Device.—The Allis-Chalmers Manufacturing Co., Milwaukee, has placed on the market the "Synchro-Operator," an automatic control device which eliminates all human element and performs rapidly the combined functions of speed matching, synchronizing, and visual phase angle indicating; these formerly required a frequency matcher, an automatic synchronizer, and a synchroscope. The "Synchro-Operator" is not much larger than the usual synchroscope and can be mounted on a swinging bracket. It accurately synchronizes generator and bus even if there is a voltage difference and it is satisfactory for both stable and erratic frequencies. The control closing instant is advanced (at a phase angle proportional to the difference in frequency) to compensate for the inherent time lag in circuit breakers, thus making the breaker close at the exact point of synchronism. One "Synchro-Operator" will serve any number of generators and can be used in connection with existing governor control motors and station circuit breakers. It consumes little energy, operates through standard potential transformer metering circuits, requires no special features on prime mover or generator, and contains no vacuum tubes.

Trade Literature

Aluminum and Alloys.—Booklet, 92 pp., "Alcoa Aluminum and Its Alloys." Presents in concise form fundamental information concerning aluminum alloys now available. An appendix includes numerous tables showing physical properties, composition, dimension tolerances, commercial sizes stocked, etc. Aluminum Co. of America, Gulf Bldg., Pittsburgh, Pa.

Pyranol Capacitors.—Bulletin GEA-77H, 28 pp., "Improving Power Factor for Profit." Describes four general types of Pyranol capacitors for power factor improvement over a wide range of service conditions and for indoor and outdoor applications. General Electric Co., Schenectady, N. Y.

Power Cables.—Bulletin, 16 pp., "Advance in Cable Design." Describes the improvements in the design and manufacture of paper insulated power cable which incorporates in its construction part or all of the following features: "compack" strand, super-dense paper, Chase shielding tape, metal binder tape, interlocking of metal tapes, and CO_2 gas treatment. General Cable Corp., 420 Lexington Ave., New York City.

Surge-Crest Ammeter.—Bulletin GEA-1934A, 4 pp. This surge-crest ammeter equipment measures magnitude, polarity, and amount of oscillation of current surges and is readily adapted to cover any desired current range between 300 and 70,000 amperes. It is particularly valuable for the measurement of lightning surges in transmission- and distribution-circuit conductors and structures. General Electric Co., Schenectady, N. Y.

Cable Laying Plow.—Folder. Extensive trenching and backfilling is eliminated with this device; cable up to 1¼ inch can be laid at a depth of from 16 to 20 inches without danger of damage to the cable. Two cables up to 1 inch diameter can be entrenched in a single operation. The plow can be handled by four men and may be pulled by either truck, winch, portable winch, or tractor. Philadelphia Electrical & Mfg. Co., 1222 No. 31st St., Philadelphia, Pa.

Electric Water Gage.—Bulletin 351. Describes the new Millipoint electric water gauge, a self-contained portable device supplanting the old hook gauge for measuring water level, and developed by R. C. Burt Scientific Laboratories in co-operation with engineers of the United States Forest Service. The advantages outlined include compactness, portability, precision, identical results obtained by different observers, speed in taking readings, wide range, and the fact that no illumination is necessary at the water surface. R. C. Burt Scientific Laboratories, Pasadena, Calif.

Lightning Arresters.—Catalog 381, 92 pp. According to the foreword the bulletin not only covers the complete line manufactured by this company, but contains a wealth of technical information on the subject of lightning protection in general. The equipment described includes crystal valve lightning arresters for both high and low voltage a-c service and for low voltage d-c service; crystal valve tank type arresters; neutral arresters and co-ordinating gaps; Garton-Daniels lightning arresters for low voltage a-c and d-c service and for high voltage d-c railway service; ground testing equipment and ground fittings. Electric Service Supplies Co., 17th & Cambria Sts., Philadelphia, Pa.

Cable Accessories.—Bulletin GEA-1839, 92 pp. As a companion book to bulletin GEA 1731 "How to Make Cable Joints" issued last year, a new G-E publication, bulletin GEA-1839 "Cable Accessories" is now available. The two books should be of interest and assistance to those engaged in work that involves the jointing and terminating of insulated cable. GEA-1731 gives clear and concise instructions for splicing, jointing, and terminating all types of insulated cable. The bulletin on "Cable Accessories" describes all the materials required for this work—joints, connectors, terminals, reservoirs, etc., and includes prices. General Electric Co., Schenectady, N. Y.

Insulation Testing.—Pocket Manual of "Megger" Practice, 128 pp. According to the sponsor this new manual is devoted to the subject of electrical insulation as it concerns those who are responsible for the installation, care, and maintenance of practically all types of electrical apparatus and is intended to be up to date and comprehensive as far as the testing of insulation resistance is concerned. Also, the new manual does not render obsolete the previous editions bearing a similar title (dating back as far as 1923). It is intended to amplify the subject of insulation testing in a manner which should be appreciated by those having to do with this fundamental factor in electrical equipment. James G. Biddle Co., 1211 Arch St., Philadelphia, Pa.